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Of COPPER *and the Manufactures dependant on Copper.*

Under this head I shall treat briefly

Of the ores of copper.
Of the assay, and analysis of copper ores.
Of the reduction or smelting of copper ores.
Of the refining of black copper.
Of the properties of copper.
Of the preparations of copper, viz.
- Sulphat of copper, or blue vitriol.
- Verdigris.
- { Distilled verdigris. / Chrystalli veneris. / Radical vinegar. }
- Scheele's green, arseniat of copper.
- Brunswick green, tartrat of copper.
- Verditer, carbonat of copper.
- Hatchet's brown prussiat of copper.

Of the alloys of copper, viz.
- Brass. Orichalchum.
- { Prince Rupert's metal, pinchbeck, similon, / Or de Manheim, Tombac. Mesure's metal, }
- Bronze.

Bell metal.
White copper. Tutenag.
The Gong. Petong.
Ancient weapons and coins.
Of plating copper with silver.
platina.
tin.

Of the ores of Copper. Copper is found native: it is also found mineralized, by oxygen, by sulphur, by arsenic, by both sulphur and arsenic, by the carbonic acid, by the sulphuric acid, by the muriatic acid, by the phosphoric acid, by the arsenic acid. It is found in the state of an ore, frequently containing iron, some times silver, some times zinc, some times antimony, some times lead; one or more of these.

Copper is found native, on the immediate vicinity of some part of Lake Superior, of which I have seen specimens, but cannot point out the place.. I have also specimens of native copper from a mine in Maryland.

The common sulphuret of copper, is found in Connecticut, in Maryland, in New Jersey, in some parts of Pennsylvania, in Virginia; but I know of no place where it is worked to profit.

The oxyds, are *red oxyd*, containing 88,5 copper, 11,5 oxygen. *Azure* or mountain blue 70 copper, 20 carbonic acid, 10 oxygen. *Malachite*, mountain green, 58 copper, 18 oxygen, 12,5 carbonic acid, 11,5 water. *Sulphuretted* copper ores: these vary greatly in the quantity of copper they contain. *Arseniated* copper ore, such as the green micaceous, the olive-green foliated, the brownish-green fibrous—these contain from 49 to 60 of copper, combined with arsenic acid. *Phosphat* of copper, greyish-black on the outside, green internally containing 68,13 of copper in the state of oxyd, and 30,95 of arsenic. *Muriat* of copper hitherto found only in Peru

and Chili. *Grey* copper ore, usually containing antimony, lead, iron and silver: poor in copper. *Brown earthy coloured* copper ores containing much iron.

The sulphurets and arsenicated ores, are those which are usually smelted for the purposes of manufacture, almost all of which contain iron also in various proportions. The copper ore at Mr. Coleman's Cornwall Furnace, contains so much iron, as to be of little value, either as copper or iron ore.

Of the assay, and analysis of copper ores. By an *assay* of an ore, is meant the process used to ascertain the quantity of metal contained in it: by the *analysis* of an ore, is meant the process used to ascertain all its component parts.

The assay of copper ores, (though by no means so accurate a method of ascertaining their metallic contents as a regular analysis) being the method by which the market price of the ore is always determined, requires the first notice. The best method, upon the whole, of conducting it, is as follows.

First, expose a small piece of the ore, under examination to the action of the blow-pipe, and by the appearance and odour of the vapour given out, it is easy to discover whether it contains any arsenic or sulphur. It may very probably contain both, in which case take 300 grains of the ore coarsely pulverized, mix it with half its weight of saw-dust, and keep it at a moderate red heat in an earthen crucible, till the disengagement of arsenical vapour entirely ceases. Then pour the contents of the crucible into an iron mortar, and reduce them carefully to a fine powder. Transfer this powder to a test, a tile or piece of earthen ware that will stand the fire and expose it to a good red heat, with occasional stirring, till both the charcoal and the sulphur are burnt off. The residue is then to be accurately mixed with one twelfth of its weight of lamp-black, half its weight of clear white sand, one fourth of its weight of dry pearl ash, and its weight of *pulverized*

glass of borax, with a drop or two of oil; the mass thus formed, is to be put into a sound earthen crucible, a cover is to be luted on, and the whole is to be placed in a good wind furnace. The heat should be moderate for the first quarter of an hour, to allow the borax time to combine with the earthy impurities of the ore; then a moderate white heat is to be applied for about twenty minutes. After this, the crucible being withdrawn and cooled, is to be carefully broken, and will be found to contain a button of copper, covered by vitreous scoriæ. The purity of the copper thus procured, is to be estimated from its colour, softness, malleability, and tenacity; after which, a part of it may be cupelled with pure lead, in order to ascertain whether it holds any silver or gold. If the ore contains sulphur, but no arsenic, it may be mixed with half its weight of charcoal, and roasted on a test, without being previously heated in the crucible. If the ore contains neither sulphur nor arsenic, it should be first moderately ignited in a covered crucible, to drive off any moisture, and may then be treated with sand, alkali, borax and lamp black, as already described.

The proper analysis, by means of liquid menstrua, is however much more accurate than even the most carefully conducted assay, and the general mode of proceeding with the ores of copper is, upon the whole, very simple. The copper, together with the other metals with which it may happen to be mixed, is to be separated from the silex and sulphur, by means of an acid, the other metals are then to be got rid of by their appropriate reagents, and the copper is then to be procured either in the state of green carbonat, of black oxyd, or of pure metal; of the first, 180 parts are equivalent to 100 of metallic copper; and of the second, 100 parts contain 80 of metal.

Previously to undertaking an analysis, a part of the specimen, under examination, should be subjected to the usual reagents, in order to ascertain, not indeed the pro-

portion, but the nature of the ingredients of which it consists; and, in few cases is this more necessary than in the analysis of the ores of copper, both as they are so numerous and so various in their composition. This previous examination being duly performed, the analysis may be conducted in the following manner:

For the analysis of the *pyritical*, and other *sulphurized ores of copper*, provided they contain neither silver nor lead, take 200 grains of the pulverized ore, and digest it at a boiling heat with muriatic acid, (adding occasionally a few drops of nitric acid) till every thing soluble in this menstruum is taken up. Of the insoluble portion, a part, consisting chiefly of sulphur, will be found floating on the liquor; and this being washed, dried, and weighed, is to be ignited on a test, by which the sulphur will be burnt off, and its amount may be estimated from the loss of weight sustained by the process. The incombustible residue is to be digested in a little warm muriatic acid, and what remains insoluble, is to be added to the other insoluble residue. The muriatic solutions being mixed together, the whole is to be decomposed by carbonated potash, and the precipitate, hence resulting, is to be digested in repeated portions of caustic ammonia, as long as this latter acquires any blue tinge. The whole of the copper, and nothing else, will thus be taken up by the ammonia, from which it may be obtained in the state of black oxyd, by the addition of a little caustic potash, and a boiling heat. The residue, insoluble in ammonia, consists of oxyd of iron, with perhaps a little alumine, which may be separated by caustic potash, the alumine alone being soluble in this fluid. Finally, the portion insoluble in muriatic acid, may be considered as little else than silex.

The ores which, besides *copper*, *sulphur*, and *iron*, contain *silver*, *lead*, and *antimony*, may be thus analyzed. The ore, reduced to fine powder, is to be repeatedly di-

gested with moderately diluted nitric acid, as long as any thing continues to be taken up by this menstruum. To the nitric solution is then to be added muriat of soda, which will throw down the silver in the state of luna cornea; this being separated, the lead is to be precipitated in the form of sulphat, by sulphat of soda; the solution is now to be supersaturated with ammonia, which will dissolve the copper, and leave behind the oxyd of iron, with probably a little alumine and silex. The copper is to be procured from the ammoniacal solution, in the manner directed in the preceding paragraph; and the oxyd of iron may be separated from the admixed earths, by caustic potash. That portion of ore, insoluble in nitric acid, is to be digested in muriatic acid, which will take up every thing except the sulphur, silex, and probably a little luna cornea. Of this insoluble residue, the sulphur is to be burnt off by gentle ignition, and the remainder is to be fused with twice its weight of pearl ash, by which the silver in the luna cornea will be reduced to the metallic state. The muriatic solution being concentrated by evaporation, and then poured into a considerable quantity of water, will deposit the antimony in the form of a white oxyd.

The simple *oxyds of copper*, are best analyzed by digestion in nitric acid, and then supersaturating the solution with ammonia, by which any casual admixture of iron will be separated.

The *carbonats of copper* are to be thus treated. One portion is to be gently calcined in a covered crucible, and the loss of weight sustained, indicates the united amount of the water and carbonic acid. A second portion is to be thrown into a known quantity of dilute sulphuric acid, and the loss of weight, by the effervescence which ensues, shows the amount of carbonic acid. The sulphat of copper thus obtained, may be subsequently decomposed, either by a stick of zinc, or by liquid ammonia.

The *arseniats of copper* are most conveniently ana-

lyzed by first moderately heating them, in order to drive off and thus estimate the water, and then digesting the residue in dilute nitric acid, by which it will be entirely dissolved; nitrat of lead is then to be dropped in as long as it occasions any precipitate, and this latter being removed, the fluid is to be evaporated nearly to dryness, after which, warm alcohol is to be added, which will take up the whole, except a white powder; this powder, and the precipitate on the addition of nitrated lead, are arseniat of lead, 33,66 *per cent.* of which is arsenic acid. The alcoholic solution is then to be evaporated nearly to dryness, and then to be digested with ammonia, which will take up the copper, leaving behind any oxyd of iron that may have happened to be contained in the ore. The ammoniuret of copper, being decomposed by caustic potash, gives the copper in the state of black oxyd, which is that in which it exists in the ore.

The analysis of *muriat of copper* is very simple. It was thus effected by Klaproth. The ore, being pulverized, was dissolved in cold nitric acid, with the exception of 1,5 *per cent.* of oxyd of iron; the solution being then diluted, nitrat of silver was added, till it occasioned no further precipitate; the luna cornea thus obtained indicated, according to the known proportions of this salt, the amount of muriatic acid in the ore. The nitrous solution was then decomposed, and the copper obtained in the metallic form, by means of a bar of iron.

Phosphat of copper was thus analyzed by Klaproth. On digestion in nitric acid, the whole was taken up except a few grains of quartz; the excess of acid in the solution was then saturated by potash, and acetite of lead was poured in till it had quite ceased to occasion any precipitate; the phosphat of lead, thus obtained, was separated from the solution, and sulphat of soda was added to decompose and precipitate the small excess of acetite of lead which had been made use of. A little sulphuric acid

was then added to the solution, and the copper was precipitated in the usual way, by means of a bar of iron.

Analysis of Copper Ores.

The number of the analysis made of the different species of copper ores is so immense, that a selection only of the most approved can here be given; and a few general rules may be premised, which will simplify the subject.

The analysis of ores is usually conducted in one of two distinct ways, the *dry* and the *moist*, each of which has its peculiar advantages and defects.

In the dry way, the ores when they contain sulphur or arsenic (which is the case with the greater number) are first *roasted* in order to dissipate the greater part of these mineralizing substances. For this purpose, in analysis in the small way, they are mixed with about their bulk of charcoal powder (or better with fine saw-dust) and exposed to a low red heat on a flat tile or muffle, or any other convenient apparatus on which they can be thinly spread. The sulphur or arsenic soon begins to rise in fumes which should be hastened by frequent stirring, keeping the heat just below the point at which the ore would run and clot together, to prevent which is one considerable use of the charcoal or saw-dust.

When no more fumes sensibly arise, and the charcoal is entirely burnt off, the part of the ore that remains now consists of the metallic portion in the state of an oxyd, still mixed however with a quantity of sulphur or arsenic, which mere roasting will not separate, and of all the earthy matrix that may have been originally contained.

The ore is then fitted for the second process, which is that of *reduction* of the metallic oxyds to the reguline state. All that is essentially necessary to reduction is, to expose the oxyd to a high heat in contact with charcoal or carbonaceous matter of any kind, and secluded from the contact of air. In reducing the metals volatile in heat, such

as zinc or antimony, this reduction requires somewhat of a different apparatus from the fixed metals, to which chiefly the present observations apply. It has been a constant custom with chemists in almost all cases (till of late years) to add to the ore in reduction, not only a due quantity of carbonaceous matter, but also to mix it with a large proportion (seldom less than thrice its weight) of some alkaline or easily vitrifiable matter to serve as a *flux* to promote the fusion of all the heterogeneous contents of the ore, and to afford a thin flowing medium, through which the globules of reduced metal can readily fall by their superior gravity, and at last be collected in a single mass or button at the bottom of the crucible.

In all the common processes of reduction, therefore, which are usually given, the additions to the ore are of two kinds, the purpose of which should be well distinguished, namely, the carbonaceous matter, which is essential to the disoxygenation of the metallic oxyd, and the saline or fusible flux, the use of which is often highly convenient and even necessary, but also often needless or even detrimental. The invariable fault of saline fluxes as generally applied, is, that they always dissolve a portion of the metallic oxyd before it has time to pass to the metallic state, and retain it permanently, thus robbing the metallic button of a part of what otherwise would unite with it: and hence it almost invariably happens that common assays made in the dry way with saline fluxes return a less proportion of metal than the ore really contains. Nor is this loss trifling in many instances, since the accurate Klaproth found a difference of 9 per cent. between the yield of copper from a certain ore assayed in the dry way, and the same ore treated in a different manner, in the moist way. As a proof of the solution of a part of the metallic oxyd in the saline flux, it may be added that the scoria, or flux after melting, is always found deeply coloured with that precise tint which would be

given, as in the common preparation of coloured glasses, by the designed admixture of the oxyd of the metal used. Thus the scoriæ of reduced cobalt ore are of a deep blue; of fine copper, green or brown according to circumstances; of iron grass-green, and the like. The loss of metal is still greater when the ore retains a portion of sulphur, which last uniting with the alkali, acts with still more power on the metallic oxyds.

As naked alkaline fluxes are peculiarly liable to this inconvenience, some eminent docimastic chemists employ with considerable success fluxes of equal power, but with less disposition to dissolve the metallic oxyds. Of this kind are very fusible glasses made of much alkali and silex without litharge or other metallic admixture, fluor spar, lime, and above all, borax. This last produces a thinner fusion of vitrifying mixtures than an equal quantity of any other substance whatever, and hence a smaller dose of this than of the naked alkalies, will answer all the purposes of a flux, and of course the loss by solution of the metallic oxyd is much less.

A reduction of the sulphuretted ores is sometimes conveniently effected by a single operation which gives a button of metal of considerable purity. The roasting, which is always a tedious operation, is saved by mixing the ore with two or three times its weight of nitre, and projecting it into a hot crucible. The mixture dephlagrates on reaching the crucible, the sulphur is burnt and converted to sulphuric acid which unites with the potash of the decomposed nitre, and the metal, now freed from the sulphur, becomes fully oxygenated by the nitric acid and ready for reduction. This is effected by throwing in a reducing flux of tartar and pitch or any similar matter, and applying a strong heat for the requisite time.

It appears, however, that though nitre is often a good and expeditious method of freeing ores from their sul-

phur, it is better not to perform the whole reduction in a single operation, but first to separate the metallic oxyd after dephlagration (which may be done by washing) and then to reduce it by a proper flux.

The reduction of the pure oxyds or carbonated oxyds of copper, whether natural or artificial, is effected without loss, and is by far the best method, simply by heating intensely in contact with charcoal in a covered crucible.—This is in fact a very close imitation of the method of reduction in the large way of the roasted copper ores, only as these latter still contain sulphur, arsenic, iron, and other foreign matters, the process requires to be repeated many times before the copper is in a pure malleable state, in each of which, the impurities separate in the form of a thick pasty scum, as already described, under the article of reduction in the large way.

In small experiments, where saline fluxes are used, these impurities dissolve in the flux (which is one of the great uses of these substances) and one or at most two operations, will suffice.

When copper is pure (that is, of a saleable purity, for it is very rarely found absolutely pure) it is soft, malleable, and of a beautiful brilliant yellow-red where recently cut or filed. On the contrary, when containing sulphur, arsenic, or iron, it is black, dense, sonorous, brittle, and more of a vitreous than a truly metallic appearance. In this state it is called *copper-matt* or *black copper* by metallurgists. Subsequent melting in contact with air, or with fluxes, removes these impurities, and if the operation be judiciously performed, the loss sustained by the matt, in being converted into pure copper is principally that of the impurities; for it is a valuable property of this metal to be much less easily oxidated, scorified, and dissolved by sulphurets, than any of the metals with which it is usually found mixed, and particularly than iron.

After all, however, the analysis of copper ores in the dry

way can only give an approximation to accuracy in the result, except in the treatment of the pure native oxyds or carbonats, which are indeed among the most valuable ores, but are those which the seldomest come under the notice of the practical metallurgist.

The analysis of copper ores in the moist way is performed in a tolerably uniform manner, the ore being first treated with an acid which dissolves all the metallic part, leaving the sulphur and silex; after which the different metals are separately precipitated from the solution, either in the metallic state, or in certain known forms of combination, from which the metallic portion can be accurately inferred.

The particular steps of many of these analysis will be presently given; the general mode of separating copper from the metals with which it is alloyed is as follows: *from silver*, by adding to the nitrous solution of the mixed metals muriat of soda, which separates the silver, as luna cornea, and leaves the copper: *from lead*, by adding to the solution sulphat of soda, which precipitates an insoluble sulphat of lead, and leaves the copper:—*from antimony*, by digesting the mixed oxyds of copper and antimony with nitric acid, which dissolves the copper and leaves the antimony:—*from iron*, by supersaturating the mixed solution with ammonia, which redissolves the copper and leaves the oxyd of iron: or else by immersing a piece of polished iron in the solution, which will separate the copper and leave the iron in solution, (a precaution to be observed here, however, will be presently mentioned):—*from tin*, by immersing a piece of metallic tin in the solution, which will precipitate the copper only:—*from arsenic*, by dissolving in nitrous acid and adding acetite or nitrat of lead which will separate the arsenic in the form of an insoluble arseniat of lead, and leave the copper. If an excess of lead remain, add sulphat of soda, as above mentioned:—*from Nickel* in the following way;

when this metal is found it is generally in conjunction with iron; and ammonia, which precipitates all the three metals from their acid solution, redissolves, when in excess, both the nickel and copper; but to obtain the copper singly, again supersaturate with muriatic acid, and immerse a piece of iron, which will separate the copper, and leave the nickel dissolved.

Copper is obtained separate, in wet analysis, in three states, in each of which the weight may be taken, either in the metallic state, or as the green carbonat, or as the black oxyd. If a piece of polished iron is immersed in an acid solution of copper it is almost instantly covered with a brilliant coating of metallic copper, owing to an exchange having taken place, a portion of the iron being dissolved, and separating an equivalent quantity of copper from the solution. As this proceeds, the precipitate of metallic copper increases, and incrusts the remaining iron, forming a bundle of ragged filaments which the slightest force will detach if the solution is sufficiently diluted. At last the solution contains only iron, and the whole of the copper is thus obtained in the metallic state, which only requires washing and drying. This precipitation is much assisted by boiling for a short time, especially at last, without which indeed the last portions of copper will hardly separate. The solution when purely cupreous is of a fine azure blue, but when converted to a solution of iron becomes green. It should be remembered, however, that for a perfect separation of copper from iron by this method, the solution should be in the sulphuric or muriatic acids and not the nitrous, for though iron will equally displace copper from the nitrous as from the other acids, the nitrat of iron is itself largely decomposed by mere heat or exposure to air, and lets fall a fully oxidated iron, which in this case mixes with the fine filaments of the reduced copper, and vitiates the result of the analysis. When, therefore, it has been neces-

sary to employ this acid in the previous part of the analysis, the metallic contents should either be first precipitated by an alkali and redissolved in muriatic acid, or the nitric solution should be evaporated to dryness, redissolved in muriatic acid, and again dried and moderately heated for some time, whereby the nitrous acid is expelled, and a metallic muriat remains for further treatment.

Instead of iron, tin or especially zinc may be used as the precipitant of the copper from its solution: these act more speedily and with equal certainty. With either of these two, as their muriat is colourless, the total absence of the copper (provided iron or nickel is not at the same time present) is seen by the solution becoming entirely void of colour.

Mr. Chenevix has also remarked * a singular circumstance in these precipitations, which is, that if the acid, (particularly the muriatic) be in excess, a quantity of hydrogen is disengaged, as occurs in the common solutions of these metals, and the whole of the copper is separated in a very short time. With muriat of copper, zinc, and an excess of muriatic acid, the separation is surprisingly rapid, and much advantage may be made of this fact in the analysis of copper ores.

It is to be observed, however, that zinc will precipitate iron as well as copper from its solutions, but scarcely any of the iron will separate till all the copper is precipitated. Thus if zinc is added to a mixed solution of sulphat or muriat of iron and copper, the first precipitate is obviously copper and little else, but at the time when the solution begins scarcely to turn blue with ammonia, a black powdery oxyd of iron mixes with the copper. Even if no iron be contained in the cuprcous solution, if there is an excess of acid, and *common* zinc (which always contains iron) be used, some of it will still appear in the precipitate; the excess of acid appearing first to dissolve

*Phil. Trans. for 1801, p. 211.

both the zinc and iron, and the latter being again separated by the zinc that remains. On this account, perhaps, iron is a more accurate reagent than zinc in these analysis. As the muriat of copper seems to yield its metal with more ease than the sulphat, it might perhaps be of use previously to convert the sulphat into a muriat by the addition of common salt. The colour immediately changes to green, which is a proof of this change of the cupreous salt.

The report of the assay will probably be still more accurate, if the precipitated copper, after being washed and dried, instead of being immediately weighed, is put into a small crucible, moistened with a drop or two of oil, covered with borax, and strongly heated for a few minutes whereby it becomes a solid button of good malleable copper.

The second state is that of the green carbonat. If carbonated potash or soda be added to a solution of copper, a green precipitate is formed, which, when washed and dried at the heat of boiling water, gives an uniform green powder. Its exact nature will be mentioned when describing the carbonat of copper, but it may be here added, that 180 parts of this carbonat are equivalent to 100 of metallic copper, and may be reckoned as such in all analysis. But as the pure fixed alkalies give a precipitate which may occasionally be confounded with this carbonat, this method of estimation is not quite so good as the following.

The third state in which copper may be estimated is that of black oxyd. If the green carbonat last mentioned (and it need not be washed with particular care nor dried) be boiled for a few moments in caustic potash, it at once shrinks considerably and becomes a deep brownish black fine powder, which is a pure oxyd of copper in its highest state of oxygenation. One hundred parts of this oxyd, well washed and dried in a low red heat for a

minute or two, invariably contain eighty parts of pure metallic copper. The ammoniated copper gives the same oxyd when boiled with potash.

It is also produced at once by adding potash or soda to the acid solutions of copper, and *boiling for a minute or two* (which last is an essential circumstance) and this is a better method of proceeding in analysis, since an excess of carbonated alkali will redissolve a part of the green carbonat, and vitiate the analysis, whereas no such effect is to be feared from an excess of the pure fixed alkalies at a boiling heat.

The leading steps of the actual analysis of some of the principal copper ores by the most accurate chemists may now be given in a few words, as a specimen of the mode of proceeding in different cases.

Of the ores composed chiefly of Copper, Iron, and Sulphur.

The vitreous copper ore was thus analysed by Klaproth.*

To 200 grains of the powdered ore muriatic acid was added in a boiling heat, which had no immediate effect, but on dropping in a little nitrous acid, solution began with violent disengagement of nitrous gas. When every thing soluble was taken up, the solution consisted of a clear green liquor on which the sulphur was floating. The insoluble part amounted to 38 1-2 grains, 37 of which were dissipated by calcination and were sulphur, leaving 1 1-2 of silex behind. The solution was divided into two parts, one to ascertain the copper, the other the iron.

Into the former a bar of polished iron was immersed, and by rest 78 1-2 grains of copper were precipitated.—The other half was supersaturated with ammonia, which first precipitated both the iron and copper, and then redissolved only the copper, leaving 3 grains of oxyd of iron, equal to 2 1-2 of metallic iron. Hence the iron, cop-

*Essays, vol. i.

per, silex, and sulphur were separately estimated. The copper is presumed to be in the metallic state in this ore on account of the violent evolution of nitrous gas. It is to be observed that by a previous trial the ore was found by the tests before described to be free from silver and lead, that is by giving no precipitate either with muriat of soda, or sulphat of soda.

The variegated copper ore was assayed by the same eminent chemist in nearly the same manner. On account of its colour and its making much less effervescence with nitric acid, a portion of oxygen is supposed to be combined with it.

The same was assayed in the dry way by being mixed with one-fourth of its weight of charcoal and roasted, then mixed with a fourth of colophony or rosin, and thrice its weight of black flux, and well fused. The result was a button of copper, but 10 per cent. less than the quantity of metal obtained in the moist way.

The yellow hæmatitic copper ore and the grey vitreous ore from Cornwall, were analyzed by Mr. Chenevix* nearly in the same manner as above described, only the whole solution was supersaturated with ammonia, and the copper separated from the ammoniated solution by boiling with potash, in the form of the black oxyd, of which 100 parts were estimated as equal to 80 of copper.

Ore of Silver, Copper, Iron, Antimony and Sulphur.

Klaproth's analysis of the Fahlerz† deserves a short notice on account of the skill with which it was managed.

The ore was first digested repeatedly with nitric acid, which dissolved somewhat less than half. From the solution muriat of soda separated some silver, and it was then tried for lead by sulphat of soda. It was next supersaturated with ammonia whereby a precipitate was left, which by subsequent treatment was found to consist of

* Phil. Trans. vol. 91. † Essays, vol. 1.

iron with a little alumine and silex. The ammoniated solution which now only contained copper, was supersaturated with sulphuric acid, and the copper separated by iron.

The first residue untouched by the nitric acid (amounting to more than half the ore) was then digested with muriatic acid, which dissolved nearly half, leaving a residue which by subsequent fusion with alkali was found to be silex, still holding a minute portion of silver. The muriatic solution was evaporated, during which it deposited a few small crystals of muriat of silver, after which water was added, which separated an abundant white oxyd, which was found by various trials to be antimony.

Oxyds and Carbonated Oxyds of Copper.

The purest native oxyd of copper is the red octohedral ore from Cornwall. This appears to consist of nothing but copper and oxygen, but, according to Mr. Chenevix,* the copper here exists in a less state of oxygenation than in any other known ore of this metal.

One hundred parts were totally dissolved in nitric acid with copious effervescence of nitrous gas. The pure blue solution was evaporated to dryness, muriatic acid was added, and a second time evaporated to expel the remaining nitric acid, and convert the salt to a muriat. This latter diluted with water gave up 88.5 of copper to a plate of iron immersed. Hence it is found to consist of 88.5 of copper and 11.5 oxygen. The particulars of this analysis will be further noticed when describing the oxyds and muriat of copper.

The pure carbonated oxyds of copper consist of carbonic acid, oxygen, copper and water. With almost any acid they effervesce strongly, and give out their carbonic acid.

Fontana was the first who clearly shewed the presence

* Phil. Trans. for 1801.

of carbonic acid in these ores. By distilling malachite *per se* in a glass retort, and collecting the products, he obtained some pure water, and a large quantity of gas, which extinguished a candle, precipitated lime-water, and by various tests was found to be carbonic acid.

The Siberian malachite analyzed by Klaproth will furnish another example of analysis. A hundred grains calcined in a moderate red heat in a covered crucible lost 29 1-2, which therefore is the quantity of the carbonic acid and water. Another 100 grains were dissolved in dilute sulphuric acid, and lost by effervescence 18 grains, which, subtracted from the 29 1-2, leaves 11.5 for the water.—The sulphuric solution decomposed by metallic zinc gave 58 grains of copper. Another portion of the malachite was dissolved in nitric acid, and the precipitate by ammonia was entirely redissolved by an excess of this alkali, shewing therefore the total absence of iron. Lastly, the quantity of oxygen united with the copper is inferred to be that which must be added to the 58 and 29 1-2 to make up the 100, namely 12.5.

The native carbonat when pure has precisely the same composition as the artificial, as Proust has clearly shewn, and will be presently mentioned.

Arseniat of Copper.

The composition of the different species of this family of copper ores as far as it is hitherto known is extremely simple, the ore when separated from its matrix containing nothing but arsenic acid, oxyd of copper, water, and some times a portion of iron. The arsenic acid is best estimated by uniting it by stronger affinity with some other metal where it makes an insoluble salt of a known and invariable composition. Lead is the best fitted for this purpose, so that when the nitrat or acetite of lead is added to arseniat of copper, a soluble nitrat or acetite of copper is formed, together with a white insoluble precipitate of arseniat of lead. By preliminary experiments Klaproth found that

100 grains of solid arsenical acid gave 297 grains of solid arseniat of lead after moderate drying, and hence 100 grains of the arseniat contain 33.66 of arsenic acid.*

For the analysis, the ore being first dissolved in nitric acid, the solution was accurately neutralized with carbonated potash, and then acetited lead was added till all precipitation ceased, a little of this salt remaining in excess. The precipitate of arseniated lead when washed and dried indicated the proportion of arsenic acid in the ore. The solution now contained acetic and nitric acids, united with oxyd of copper and potash, and a little acetited lead; from which the lead was first separated by sulphat of soda, that precipitated it in the form of an insoluble sulphat, after which a little sulphuric acid was added to engage the copper, and this metal in its turn was separated by polished iron in the usual manner. The copper however is thus obtained in the metallic state, but in the ore it is an oxyd, and therefore one-fourth of the weight of the copper must be added for oxygen, that is (as in the actual analysis) for 40 parts of metallic copper, 50 of the oxyd of copper must be estimated. It is necessary to neutralize the nitrous solution at first, as the arseniated lead is very soluble in acids, and therefore would not otherwise be properly collected.

Where iron is suspected in the ore, the solution instead of being finally precipitated by polished iron may be decomposed by ammonia, and the copper separated from the iron by an excess of the alkali.

As many acids form a white precipitate with the solutions of lead, the powder in question is proved to be arseniat of lead by digesting with sulphuric acid, which displaces the former acid, and leaves it uncombined in the liquor; and arsenic acid is detected by various methods mentioned under that article, particularly by giving

* Klaproth, vol. ii. 148.

a brick-red precipitate with nitrat of silver, the arsenic acid being first neutralized with soda.

Mr. Chenevix analyses the arseniats of copper in the same general way, but with some variations.

The ore (previously heated moderately to expel and estimate the mere water) is dissolved in dilute nitric acid and nitrat of lead poured in. The solution (containing an excess of acid and therefore holding some of the arseniated lead dissolved) is then evaporated nearly to dryness, and alcohol added to complete the separation of the arseniat of lead. After which the copper is decomposed by potash, and is obtained in the state of the brown oxyd.

Muriat of Copper.

The composition of this singular ore, found hitherto only in Peru, was ascertained nearly at the same time by Proust, and by Rochfoucault, Beaume, Fourcroy and Berthollet, a committee nominated for the purpose by the French Academy. The experiments are instructive.

The ore thrown on hot coals burns with a beautiful blue and green flame, whereas malachite, which it most resembles in appearance, gives only a faint green flame. Distilled *per se*, malachite gives no other volatile product than carbonic acid and water; whereas the muriat gives in the same process a quantity of oxygen gas with only a very small proportion of carbonic acid, and a green liquor strongly smelling of muriatic acid and proved to contain copper by giving a fine blue with ammonia. The residue in the retort was a brown oxyd of copper. This when exposed to air turns green, shewing therefore that it is not a simple, but a muriated oxyd. Part of the muriat of copper therefore is volatilized, as it is well known that this salt readily rises in distillation. The muriatic acid however is not sufficient in this ore to saturate the oxyd of copper, and hence by simple boiling in water only a small portion is dissolved, which gives luna cornea with nitrat of silver.

This ore was analyzed by Klaproth in the following simple manner, its general contents having been ascertained by the above-mentioned experiments. One hundred grains of the ore were dissolved in nitric acid without heat, during which about 1 1-2 of iron ochre was deposited. It was then diluted and nitrat of silver added to ascertain the quantity of luna cornea. Of this last, 64 1-2 grains were obtained, of which 10 grains were muriatic acid, according to separate experiments by which it appears that 100 grains of silver form 133 of luna cornea, and of the 33 grains additional weight, 12 1-2 are oxygen, and 20 1-2 muriatic acid. The copper was then precipitated as usual by iron, and weighed 57 1-2 grains in the metallic state, equal to 73 of the brown oxyd. Klaproth does not consider the iron however as essential to the ore, and therefore excludes it from the estimate.

Phosphat of Copper.

This rare metal was analyzed by Klaproth in the following way. It was first dissolved in nitric acid, which made a clear blue solution, leaving untouched 16 parts out of 100, which were quartz. The solution was then just saturated with potash to engage any excess of nitric acid, and acetited lead was then added, which gave a copious white precipitate, and a small excess of the acetite was used to ensure the complete precipitation. This white insoluble salt from appearance might be either sulphat, or arseniat, or muriat, or phosphat of lead, but it was proved to be the latter by the two following tests: 1st. when fused by the blowpipe, in the moment of cooling it assumed a garnet-like form with shining surfaces, which sudden crystallization is peculiar to phosphat of lead; and 2dly, when digested with dilute sulphuric acid, sulphat of lead was formed, and naked phosphoric acid remained in the liquor, which being neutralized, partly by soda and partly by ammonia, gave the well-known microcosmic salt. The native phosphoric acid was there-

fore separated from the copper in this analysis, and from 100 grains (exclusive of the quartz) 138 grains of phosphat of lead were formed, the phosphoric acid of which was estimated from other experiments to amount to 30.95 grains. The cupreous solution was then treated with a little sulphat of soda, to separate the lead from the excess of the acetite remaining; some naked sulphuric acid was then added, and the copper was separated by iron in the metallic state, which (increased in the proportion of 125 to 100), was found equal to 68.13 of oxyd of copper.

The above analyses include almost all the important ores of copper, except those in which it is combined with tin, which will be treated of under that metal. It may be mentioned however that the most accurate way of separating copper from tin appears to be to immerse in a solution of both metals a stick of tin, which will precipitate all the copper, whilst the loss of weight of the immersed tin subtracted from the entire quantity of tin afterwards obtained from the solution, will indicate the quantity of tin belonging to the ore. [1 *Aikins Dic.* 327.

Of the Reduction of Copper Ores.

The only ores of copper in fact that are wrought in the large way, and from which the copper of commerce is for the most part supplied, are the sulphureous and arsenical ores of this metal. The method of reducing them, though consisting of a great number of processes, on account of the powerful affinity, both of the arsenic and sulphur, is yet upon the whole very simple, being little more than repeated roastings and fusions, till the metal has acquired the necessary ductility, for it is never brought to a state of absolute purity, and the commoner sorts contain both arsenic and antimony, in such proportions, as to be wholly unfit for alloying with either gold or silver.

The rough ore, if simply sulphureous, is broken into pieces not larger than an egg, and separated as much as

possible from the adhering earthy impurities; after which it is piled in large kilns, and heat being applied at the bottom, the whole mass becomes gradually heated, and a large portion of the sulphur sublimes out, and may be either collected by proper flues, or allowed to escape; this first process occupies about six months, at the expiration of which time, the evaporation of the sulphur ceases, and when the ore has cooled sufficiently, it is in a fit state to be smelted.

If, however, the ore is largely combined with arsenic, it is not capable of keeping up a long combustion of itself, nor is the heat thus generated adequate to the expulsion of the arsenic; a somewhat different method, therefore, of roasting must be had recourse to. For this purpose the ore is still more carefully dressed than in the former case, and is reduced to pieces not larger than a hazlenut. It is then spread on the floor of a large reverberatory furnace, and exposed to a dull red heat, with frequent stirring, in order to offer fresh surfaces to the action of the flame. The arsenic and sulphur by this treatment are rapidly driven off, and in about twelve hours the roasting is completed.

The ore is now transferred into the fusing furnace, which is a reverberatory of the common construction; a little bruised lime-stone is generally added by way of flux, and in the course of four or five hours the fusion is usually complete; the slag, now of the consistence of soft dough, is raked off, and the copper is discharged through a plughole into water, by which it is reduced into small drops or grains.

The copper, however, though in the metallic state, is still very impure, being largely mixed with sulphur and arsenic, which give it a grey colour, and render it perfectly brittle. In order to separate these impurities, it is remelted and granulated twice more, or oftener, a considerable quantity of slag being separted at each fusion; but as

this slag contains some copper it is not thrown away, but worked over again with the next charge of calcined ore. The number of fusions and granulations entirely depend on the quantity of impurities, and the obstinacy with which they combine with the copper; but when these processes have been repeated the requisite number of times, the granulated mass is melted and cast into pigs. These again are broken to pieces, and roasted for one or two days in a low red heat, and again melted and roasted several times, till the metal approaches to the state of malleable copper. It is now cast into oblong masses, about 14 inches in length, and is fit for the refining furnace. In this it is again melted, with the addition of a little charcoal, till it acquires the necessary degree of malleability, and thus becomes saleable copper.

Sometimes lead is employed with good effect in the refining of copper, as it combines with, and scorifies iron, and the other easily oxydable metals in preference to copper. For this purpose the rough copper is spread on the floor of a furnace, and when it is in complete fusion, about 6 or 8 *per cent.* of lead is thrown in, and well mixed with the rest. In a short time the surface of the melted metal becomes covered with a semi-vitreous blackish-brown scoria, consisting of the mixed oxyds of lead, iron, and other impurities, together with a little copper. The first scoria being removed, a second is formed, which is in like manner scummed off, and so on successively, till, after ten or twelve hours the copper is sufficiently purified: this is ascertained by the thinness of the film with which the melted copper is covered, and by its being of a brick-red colour, also by the circumstance that if a rod of polished iron is dipped into the fused mass the portion of copper that adheres to it immediately falls off when the rod is dipped in cold water.

So far the editors of Rees's Encyclopædia: but the process is not so easy, and deserves to be treated more at

length; I shall therefore present the reader with other accounts, not regarding the chance of some tautology, and repetition.

Reduction of the Ores.

The reduction of copper ores in the large way is on the whole a very simple business, being little else than a succession of roasting and reducing processes of the simplest kind, till the metal acquires the desired degree of malleability and purity. It is to be observed that both arsenic and sulphur adhere to copper with great obstinacy, even long after it has assumed the appearance of a pure regulus, and even in very small proportion they make the metal brittle, hard, and difficult to work.

There are scarcely two works in which precisely the same order is observed in the different reducing processes (supposing the quality of the ore to be the same) and as the manufacturer is generally satisfied with that which has been long established and is attended with ordinary success, he seldom enquires whether the labour may be shortened or the expense diminished.

The sulphuret of copper which is obtained in such vast quantities at the Parys mine in Anglesea, is wrought into rough copper in the following manner. The ore is dug up in large pieces (being mostly obtained by blasting) and is first broken into smallish lumps by the hammer, chiefly by women and children, and put into a kiln from which proceed flues that open into a very long close penthouse gallery to collect the sulphur. The kiln is covered close, and a little fire is applied to the mass of ore in different places, whereby the whole is gradually kindled. The sulphur then rises in vapour to the top of the kiln, and thence through the flue into the long gallery, where it slowly condenses, and is afterwards brushed out and further prepared for sale. The mass of ore when once kindled continues to burn of itself with a smouldering heat for about six months, during which time the sul-

phur-chamber is cleared out four times, after which the ore is sufficiently roasted. The old sulphur-chambers are on a level with the kilns and of the same length and height, or in fact they are a prolongation of the kilns: but the more modern and improved chambers are like lime-kilns, the ore being at the bottom, and the sulphur subliming at the top, with a contrivance to take out the roasted ore, and thus to keep up a perpetual fire.

The richest part of the roasted ore is exported without further preparation, but the poorest part is smelted on the spot. It still contains a vast quantity of sulphur and other impurities. The smelting houses are a range of large reverberatory furnaces, thirty-one of which are under the same roof, ranged side by side in a single long row. They are all air furnaces, the chimneys of which are 41 feet high, which causes a most powerful draught through them. The fuel is coal, which is burned on a grate at the anterior part of the furnace, and the flame in drawing up the chimney passes over the bed of the reverberatory, into which is put 12 cwt. of the roasted ore, previously mixed with a small portion of coal dust. The ore is here melted and reduced into a very impure regulus, and when sufficiently fused it is drawn off through a plug-hole into earthen moulds. A single charge of the furnace, or 12 cwt. yields 1-2 a cwt. of rough copper, which by further purification affords about 50 per cent. of pure malleable metal. The furnaces work off a single charge about every five hours.

The copper furnaces in Cornwall are also of the reverberatory kind. The ore when drawn up from the mine is first broken into pieces no bigger than a hazle-nut, which operation is called *cobbing*, and the better sort is picked out by hand. The reduction begins by the process of roasting in large reverberatory furnaces 14 feet by 16, the bottom or bed of which is made of fire-bricks and covered to the thickness of about two feet with silicious

sand, which runs together by the heat into a semi-vitrified mass. The chimney is from forty to fifty feet high, which causes such a powerful draught that the arsenic and sulphur separated during the roasting pass almost entirely through the chimney into the open air, none of it being collected as at Anglesea. The ore is spread over the bottom of the furnace about a foot thick, being thrown in through a kind of funnel or hopper just above. The fuel is Welsh coal, which, as usual, is burnt at the anterior part of the furnace, and its flame draws over the surface of the ore in its passage to the chimney. In this furnace, which is called the calcining furnace, and is the largest of all, the ore is roasted without addition with a dull red heat for 12 hours and is frequently in that time stirred with a long iron rake, introduced through a hole at the further end of the reverberatory, to expose fresh surfaces to the action of the flame. The ore is not melted here, but when roasted sufficiently, it is carried to another furnace exactly similar to the former, but smaller, that is, about 9 feet by 6, and here it receives a fusing heat, but still without any addition, except that when the slag does not rise freely, a little calcareous sand is thrown in. At the end of every four hours the slag is raked out; it is then of the consistence of soft dough and is laded into oblong moulds, and a little water is sprinkled upon it to make it sink down, after which the moulds are quite filled with it, and when cold it makes hard solid blocks of slag about 14 inches long and 12 deep and broad, which are used for building. After the slag is raked off, a fresh charge of calcined ore is let down into the reverberatory, and the copper is tapped off by a hole in the side of the furnace, which before the fusion had been stopped up with a shovel full of wet clay mixed with about a fourth of new coal, which prevents the clay from hardening too much, so that the hole may readily be opened by an iron pick.

The rough copper as it runs from the surface is con-

veyed by a gutter into a large kind of bucket suspended by chains in a well through which a stream of water is passing, and here, in falling into the water, the metal is granulated, which takes place without explosion or danger, and it is then drawn out by raising the bucket.

The copper is still however extremely impure, though apparently in the metallic state, being grey and perfectly brittle, and still mixed with arsenic and sulphur, to separate which is the work of several subsequent processes. It is then remelted and granulated twice more, or oftener, each time throwing up a slag in the furnace, which is removed before the plug-hole is tapped; but as this slag contains some copper, it is not cast into moulds as the first, but worked over and over again with the fresh charges of calcined ore. The number of fusions and granulations is entirely determined by the nature of the ore. The granulated mass is then melted and cast into pigs, which have a blistered appearance on the surface, and are broken up and roasted for one or two days in a low red heat, and again melted and roasted as before for several times till the metal is considerably purer, and at last is cast in oblong iron moulds about 14 inches in length, when it is removed to the *Refining Furnace.* Here it is again melted with the addition of a little charcoal, till it is brought to a sufficient purity to bear the hammer, and is now good saleable copper.

It is observable that in the former process when the crude and brittle metal is cast in sand in the form of large pigs or ingots, the best part of the copper rises to the surface, and when cold may be knocked off with a hammer, forming a brittle crust about three-quarters of an inch thick, of a grey colour and a steel-like fracture.

Thus by a series of successive calcinations and fusions in the simplest manner possible, the common copper ores are freed from arsenic, sulphur and earthy matters, and gradually brought to the state of malleable copper. Where

a variety of ores from different places and of different species are brought to the same smelting-house (which is the case in many of the houses at Swansea and different parts of the Bristol coast) much technical judgment is exercised in sorting the ores and distributing the charges for the furnace in such a manner that the more fusible will assist the reduction of the refractory, and the poorer will be made more worth working by the addition of a portion of the richer ores, and the like.

The subsequent operations whereby the ingots or pigs of malleable copper are formed into sheet copper, wire, nails, bolts, cauldrons, and an infinite variety of manufactured articles, do not come within the province of pure chemistry: it may be sufficient to observe that the hammering renders the metal much more uniform, close, and ductile, but this requires to be frequently alternated with annealing at a full red heat, to prevent the metal from cracking under the powerful pressure to which it is exposed. Immediately after the last annealing, the copper plates are quenched in urine, which somewhat hardens the surface, and gives it that redness which is considered by the merchant as one mark of the purity of the metal.

In the reduction of the copper ores of Neusol in Hungary, lead is used in the refining part of the process* in the following manner: the rough copper is spread on the bed of a furnace, and when it has been six hours in fusion, some lead, in the proportion of from 6 to 8 per cent. of the copper, is thrown in, which immediately begins to vitrify and to form a thick scoria along with the impurities of the copper, which is scummed off successively till the whole is exhausted and the copper remains fine and clear. This process lasts from ten to twelve hours, with fifty quintals of raw copper. The scoriæ retain a portion of copper, which makes it answer to work them again.

* Jars Voyages Metall. tom. 3.

The power which the vitrified oxyd of lead has to scorify all metals, except gold, silver and platina, is amply shewn in the process of *Assaying*, and hence it must happen that in refining, some of the copper becomes oxidated together with the lead; but the same process of assaying shews that copper requires a large portion of lead for this purpose, and therefore the latter metal in so small a proportion as 6 to 8 per cent. is probably a most useful addition where not too expensive. For of all the common imperfect metals, copper is that which scorifies and oxidates with most difficulty when in fusion, and therefore the same method, with some little variety, may be practised to separate lead and tin (for example) from copper, as any or all of these metals from silver or gold, care being taken in the former case not to carry the scorification beyond what is necessary to separate the more easily oxidable metals from the copper which then remains in the metallic state. This will be further noticed in the succeeding article of *Alloys of Copper*, and the purification of bell-metal. After the greater part of the lead has been worked off as often as is judged necessary, the remaining copper must be kept for a while longer in fusion, to throw up the last portions of lead that may adhere. In assaying gold or silver the total expulsion of the lead is known by the fine metal becoming at once brilliant on the surface, but in refining copper this appearance can never take place, as the copper itself always forms a thin oxyd on its melted surface; and therefore, to judge whether it is pure, the workman dips a polished iron rod in the melted mass, and draws out a portion of copper adhering to it, which, if pure, immediately falls off when the rod is dipped in water. The colour of the scoria is also another test. While the copper remains impure and alloyed with iron, sulphur, &c. the vitrified oxyd on the surface is black or of a dirty brown, but the scoria of pure copper is red, and also is readily separated from the iron when cold, leaving no stain behind.

The plates of fine red copper, called *Rosette Copper*, are made in the following way.* When the refined copper is found by the way just mentioned to be sufficiently pure, the surface of the melted metal is well scummed and suffered to cool till it is ready to fix, at which time a workman brushes it over with a wet broom, which immediately fixes the surface and causes a thin plate to separate from the still fluid metal below. This plate is taken off and thrown into water, where it takes a high red colour, and the same process of wetting the surface is repeated with the remaining fluid metal successively, till the whole is reduced to these thin irregular plates.

A considerable quantity of copper is obtained from the springs of native sulphat of copper or blue vitriol, which are found in most copper mines or flow from hills containing this metal. To obtain it, the vitriol water is pumped up into large square open pits, two or three feet deep, made with rammed clay, into which is thrown a quantity of refuse iron of any kind, and suffered to remain for a considerable time, during which the iron is dissolved, displacing by superior affinity the copper which is precipitated in the form of a brown mud. When the water is thus exhausted of its copper, the pits are raked out, and the oxyd collected from them is simply dried in the sun. It is then fit for reduction in the reverberatory furnaces in the usual manner. This is by far the richest material employed, for, though containing some clay and iron mixed with the copper, it yields on an average full 50 per cent. of pure metal, and therefore it is seldom smelted by itself, but mixed with the poorer ores, some of which contain no more than five per cent. of metal.

Many of the finest copper ores contain so much silver as to make it worth while to extract this last metal by a separate operation, which will be described under the ar-

* Macquer Chem. Dict.

ticle *Silver*. In all the different roastings and reductions necessary to bring the copper to purity, the silver remains united with it. [*Aikin.*

I have translated the following account from Hellot's Schlutter, v. 2. p. 496; it is the substance of the best methods detailed by him. His work, like that of Jars, who wrote long after him, contains not only detailed accounts of the processes of various works, but plates of the various furnaces in use. I give none of these, being persuaded that the well known and long-approved Cupola furnace of the lead and copper works of England, is preferable.

At the Bristol foundery, they smelt the copper ores of Cornwall, Devonshire and New York, in a reverberatory furnace such as is used for lead. The ore is broken into small pieces of the size of a walnut. The hearth is made of sea sand: the basin that receives the metal let out, is made in the same way. They are baked by the heat of stone coal. The ore is also heated in the same manner which serves also for roasting. This poured on the hearth through a hole in the arch by means of a hopper, and the hole is then closed: it is thus fed with four quintals of ore every four hours. The coals are lighted on a grate on each side of the hearth, and the flame reverberates on the ore from the arch, as in a red-lead furnace: the ore is thus roasted and then melted. The scoriæ are raked off by an opening left for this purpose. The matt, or crude metal, is run off every 24 hours. This furnace is kept in blast for a twelve month together.

Secondly, The *crude metal* broken in pieces, is placed on the same kind of hearth in another furnace, and kept under the flame of the reverberatory for 18 hours: it is then let out into a basin or reservoir of sea sand, sometimes cemented by being mixed with finely powdered glass, and then exposed to strong heat. This operation,

termed roasting, is repeated 8 and sometimes 12 times before *black copper* can be obtained. When this appears, it is let off, and run into ingots, which are again exposed to the reverberatory till the copper is quite purified. This is let off and granulated by falling into water while in a melted state.

Such a reverberatory may be worked by wood as well as coal.

The hearth and basin (catin) may be made of sand as above mentioned, with a thin coating of pounded and sifted glass, which when melted, unites the surface into a compact body. Sometimes they are made of one part by measure of clay, and two parts or more of charcoal dust with one measure of well burnt pounded brick or fire stone: all these are moistened, well mixed, and well beaten with flat wooden and iron pounders, and rammed.

The flux is sometimes (in England) common salt, and sometimes broken glass, and scoriæ.

Refining.—This is for the purpose of scorifying any iron, lead, zinc, tin, antimony or cobalt that the metal may contain.

The furnace is in shape of a table 2 feet 6 inches from the ground, 6 feet 6 inches wide and 4 feet 6 inches deep. At the distance of 9 feet 3 inches from the ground, an arch is raised, and on this arch a chimney, and the wall against which the furnace is supported. At the sides of the furnace, a door-way is left, the height of a man, to clear the surface of the melted metal. The bottom should be as high as the underside of the air pipe or tuyere (tweer) and hollowed out by means of an iron cutting ring with a slanting edge, 6 feet 6 inches diameter and 9 inches deep: well beaten, and made smooth, and then dried by gradually heating it. A strong blast from a pipe of one inch diameter should play full on the surface of the melted metal covered with coals. There must be also a hole left near the tweer

to introduce the Trial Iron into the metal exposed at the nose of the blast. The metal being perfectly melted, the blast should be continued, with fresh coals for half an hour: the copper being less oxydable than the metals mixed with it, these rise in scoriæ to the top, and are removed occasionally by the refiner, by raising them with pointed sticks, and then raking them off as quickly as possible lest the metal should cool, first removing the hot coals all round and stopping the blast: the surface is again covered with hot coals, and the blast renewed. When the surface affords no more scoriæ, the refiner tries the metal with the iron which is a rod of about 3 feet 6 inches long, about as thick as a finger, and pointed with polished steel. This is heated moderately, and plunged quickly into the melted metal of which a part sticks to the iron. If it removes easily from the iron, and is of a good colour and all smoke is over, the fire is continued enough. If it sticks too hard to the iron, the metal is not yet pure.

If pure, the surface of the copper is sprinkled (not splashed) with water, and the congealed plates are taken off with pinchers, and is the rose copper, or Rosette.

As the blast strikes the copper, care should be taken that it does not blow away the coals, which also may now and then be sprinkled to prevent their flying off. Care also should be taken to keep the mouth of the bellows clean, and the sides of the basin should be so managed that the inclination of the melted matter should be slightly toward the bellows or tweer.

If there should not be metal enough to fill the basin so that the blast shall strike on the melted metal, a charge of copper already refined should be put in, or the whole mass may be stirred upward, with a stick of wood, which when burnt away may be supplied by another.

When the Rosettes are taken off by the pinchers, they should be plunged into water obliquely by the edges, not

flat, otherwise some parts of the hot copper not quite fixed, may be thrown off against the workman.

The essay should be frequent: when finished, the copper throws out small globules and is red, and filamentous with few yellow spots. The scoriæ from being black, become brown and brownish red, and emit no smoke.

When the refining is carried further than is necessary, the plates are thicker, the under side also is full of pointed drops, but the metal is not the worse.

If the copper is not sufficiently refined, the plates are of unequal thickness, and have inequalities of a dark colour near the edges, or the metal has pale coloured spots in its fracture.

The refining hearth may be near the foundery furnace: it may be of fire stone, fire brick, or brasque.

The refining occupies from an hour and a half to two hours.

If the basin must be emptied, it may be done by ladles well covered with clay inside and out.

The scoriæ should always be so removed, that the blast may strike the surface.

The hearth ought to be examined and mended after each operation.

There should be an iron ring to retain the coals.

I shall now proceed to give the processes used at the mines of Fahlun, in Sweden, and Tresburgh near Brunswick, in Germany, from 3 Jars Voyages Mineralogiques.

I select these, because the Swedish copper is very good, and because the works at Tresburgh were under the direction of M. Cramer, whose skill is well known. At Fahlun, they do not find it necessary to wash the ore: at Tresburgh it is washed, after being broken, and sorted, and sifted.

At Tresburgh, owing to the quantity of fluor spar that accompanies the ore and assists the fusion, the ore is not

previously roasted. But at Fahlun and many places in Germany, the ore is roasted in the open air, upon a levelled platform of earth about 14 feet long by 7 feet 6 inches broad. The bottom is well covered with billets, on which the ore is laid and heaped up to the height of about 5 feet 6 inches. The more sulphurous and pyritical pieces are in the middle, the richer on the outside. The sides are covered with the dust of the ore sufficiently thick to retain the heat. Holes are made at the top for the sulphur and fume to escape. The fire is gradually kept up for a month or more. The mass is then opened, and the ore carried to the furnaces for *smelting* the copper into a *matt*, which is afterwards carried to the refining furnace.

Of these furnaces, both Schlutter and Jars give plates, (Schlutter plate 32, Jars vol. 3. plate 3). The smelting furnace at Fahlun, is made thus: upon an arch open at each end, surrounded by masonry (the arch being preferred to avoid the quantity of moisture which solid masonry would furnish) a platform of brasque, a composition, half clay and half sand, is laid and well beaten; four or five feet square. On this another composition is well beaten of equal parts of clay and charcoal dust. This is hollowed out to 15 inches deep, leaving the two layers of brasque at least six inches thick. At this level of 15 inches from the bottom is placed the nose of the tuyere. The bottom has a gentle inclination to allow the melted matter to run and gather to one end. The furnace is about 3 feet by 3 feet 6 inches and about 4 feet 8 inches high. It is well dried by being gradually heated. It is charged with charcoal and ore. The front is made up with fire stone or clay, and the furnace tapped as occasion requires.

At Fahlun, sometimes the ore is roasted in furnaces appropriated to this purpose, where it receives seven or eight firings.

The matt, or produce of the first smelting of the roasted ore, is again melted in a similar furnace of smaller dimensions, where it produces large pigs of black copper. The details of all this are best given in 2 Schlutter, p. 492, who also treats at large on the refining of copper.

The refining furnace, is about 3 feet 8 inches by 3 feet 2 1-4 inches deep. The tweer of copper has an inclination of about 25 degrees, and the blast is directed toward the most distant part of the furnace. The basin of the furnace, is made of a composition of two parts well tempered clay, beaten up with one part charcoal dust and one part cinders. Of this composition or brasque there are three layers. When well made, it will last for three or four refinings. The loss amounts to ten per cent. The copper is taken out in rosettes as above described.

At Tresburgh the furnace is 5 French feet high, 3 feet deep, 16 inches wide at one end, and 21 at the other where the tweer enters, which is not elevated above 4 or 5 inches above the basin of the front hearth.

The copper undergoes repeated fusions at the refining, till it becomes pure, which is tried as has been already mentioned in the case of the English furnaces.

The following note I copy from some manuscripts lent me by my much respected friend Dr. Hunter of Philadelphia.

Copper Refined.

Memorandum of a process for refining *copper* at one smelting, given by Mr. Francis Da Costa. The koppерpys (the ore) are put into an air furnace, which is first heated slowly to give an opportunity for the sulphur and other volatile metallic substances such as antimony and arsenic to evaporate—half an hour afterwards increase the heat to fusion. Then throw on the surface of the metal a layer of fine white clear sand which melts and dissolves

a mass of cinder at the surface. When formed take it out with a scraper and let the metal remain in a fluid state long enough to allow the remaining oxydable substances to come to the surface, and then renew the operation with sand should that second operation prove necessary; and let the cinder be again scraped out. Then throw on the surface of the fluid copper, powdered charcoal to carry off the oxygen remaining. When this charcoal is burnt down, dip into and stir the copper well with a stick which whilst burning, occasions an ebullition which throws up to the surface those parts of the metal, that had not been in contact with the coal, and throw some more coal upon it and renew the operation until you ascertain, that the refining is complete which is easily done by taking out a little of the melted copper with a small ladle; cast, cool and break it, if the metal appears silky and of a good colour, the metal is pure and fit for any purpose—when cast into large thin moulds, it requires to be very hot, and at the same time the moulds ought to be very dry, to prevent accidents, or the losing the intended casting piece. Mr. Da Costa believes that this process depends on the difference of affinity between copper and iron, which last is the principal impurity in the copper brought from the Spanish main.

N. B. G. H. has examined several samples of copper brought from Spanish America and never found any iron in them—he generally found sulphur and antimony.

Perhaps powdered magnesia (manganese) would have a good effect in separating the semi-metals, which are commonly found in a small proportion in copper in pigs, and thereby facilitate the malleability of it, by stirring it well with the melted copper. Nitre is too dear.

Having now given some ideas of the mode of working copper ores, from writers who have treated on the subject, I will give the substance of my own notes, taken on a

tour to Amlwch or Amluch, in the isle of Anglesea which I visited in the year 1791, solely from curiosity to see the Parys copper mine of that island.

We (I and Mr. Baker, a proprietor of oil of vitriol works, who wished to purchase sulphur at Anglesea; the Mr. Baker, who combining some experiments of my own and Mr. Charles Taylor's, struck out the most perfect and compendious system of bleaching yet known) went to Chester from my residence at Altringham.

At Chester, a town of little trade, *for it is a borough or corporation town*, there is nothing remarkable but the porticoes of the street, hollowed out of the rock. The country people of Wales, sell there, their home made woollen stockings, such as are here sold for 75 cents, at 10 pence sterling per pair by the dozen. (1791). It will be a long time before the raw material wool, is as cheap in America as in England.

After leaving Chester, toward Conway, we found nothing but Welch spoken by the commonalty: I know of nothing so amusingly strange to an English ear, as a Welch scolding match, with which we were more than once entertained. Not a word of English from thence to Anglesea "dim sausenick" I do not understand Saxon, or English, was the common reply. There is no such utter ignorance in this country.

After visiting the ruins of Conway Castle, we took chaise (the Landlord of the inn refusing to let us have one unless with four horses) toward Anglesea, over Penman Maur.

The road is dug on the side of the rock, and imperfectly made. A wall about five feet high protects the traveller from an abrupt precipice of about a hundred and fifty feet below, the sea for a great part of the way washing the foot of the rock; on the side of which, we had to pass over a road from ten to sixteen feet broad. We slowly

followed the stage coach; which was conducted with great caution by the driver, over a part of the road where the mountain overhung the carriage; the wall was to the right, and a large shelving rock not blown up in the pathway of the road, required all the circumspection that could be employed. All was not enough. The coach tilted when it came upon the stone in the road; it fell upon the wall; and Mr. Baker and I, scrambled over, just in time to take the passengers out at the window on the side of the wall toward the precipice. The coach balanced on the wall. We put up at a tavern on the Anglesea side of the Menai: there as at every other tavern where we stopt between Chester and Anglesea, a harper introduced himself: and without further ceremony than the first obeisance, struck up the national tune "of a noble race was Shenkin."

We passed in our road from Chester, Holywell, a flourishing little town, containing as I think the largest spring of water in the kingdom, turning many cotton works. But I know nothing more of it.

We went to Amlwch, or Amluch as the English pronounce it. I cannot imitate by writing or by sound, the guttural pronunciation of the Welch. The English with the vulgar impoliteness of ignorance laugh at Americanisms. I confess we can do without *lengthy*, and *illy*, and *predicate:* these are not expressions, which will justify our national literature in taking what we call "*high ground.*" And notwithstanding the excellent defence made in behalf of our language by the editor of the Port Folio against the ignorant and hasty sarcasms of the Edinburgh Review, I could wish Mr. Barlow in his Columbiad, had been more sparing of his novelties in language—novelties that he may own if he pleases, but which do not belong to us. Still our representatives do not *deal in truisms*—nor do they move Mr. Speaker *to appoint a short*

day—nor are they *free to confess* that they differ from the right honourable gentleman *in their eye*, &c. &c.

But where is the civilization of Great Britain, when the Welch, the Irish, the Scotch, the Border, the Yorkshire, the Lancashire, the London, the Somersetshire, and the Cornish dialects, are mutually unintelligible to the inhabitants of each? Bring together an inhabitant of Ormskirk or Poulton in the Fylde in Lancashire, and Redruth or Truro in Cornwall, and although each would talk English, they would understand each other, about as much as an Hottentot and a Cherokee. There is no such disgrace in America. Five and twenty years may have lessened it in England, but it existed in great force at that period.

We went to the Parys mountain, which is about a mile long. It is excavated from the top downward. All is open to the day. No shafts, no levels, the ore is drawn up to the top.

The kinds of ore, are the common yellow sulphuret of copper—azure or mountain blue—malachite or mountain green (carbonats)—Black copper ore, contaminated with sulphuret of lead, black jack and calamine—sulphuret of copper or blue vitriol chrystallized, and in solution, which is pumped up—sulphat of lead, and the dog-tooth lead ore.

There is also found in small quantities, native copper—and some native sulphur.

The copper and sulphur in the best part of the ore, are about equal in quantity. The dirt of the gangue or matrix amounts to nearly one half.

In roasting the ore, the miners have a notion that the metal becomes concentrated in the middle of the lump. But this is a mistake. The middle part is most solid and heavy, because it is less acted on, by the heat, the air, and the sulphuric acid formed during the combustion of

the sulphuret. Much valuable matter appeared to me to be washed away. Much blue vitriol (sulphat of copper) and much green vitriol, (sulphat of iron) might be made there; but the copper is usually precipitated from the copper water, by immersing bars of iron in it.

In my time, they did not save the sulphur, but let it burn away. A few years afterward, Mr. Thomas Henry of Manchester, elder brother of Dr. William Henry the chemist, went to Anglesea, to contract for the sulphur that might be saved by roasting the ore with an appendage of long flues, and a chamber to save the sulphur sublimed, which he proposed to introduce. But the scheme did not answer *to him.* I believe the sulphur contained some arsenic, which rendered it unfit for the oil of vitriol manufactory.

Mr. T. Henry afterward died in South America, as a supercargo for Nicklin and Griffith of Philadelphia.

The following account by Mr. Arthur Aikin, who was at Anglesea in 1796 coincides with my own.

Process.—The ore is got from the mine by blasting; after which it is broken into smaller pieces by the hammer (this being chiefly done by women and children), and piled into a kiln, to which is attached by flues a long sulphur chamber. It is now covered close; a little fire is applied in different places, and the whole mass becomes gradually kindled; the sulphur sublimes to the top of the kiln, whence the flues convey it to the chamber appointed for its reception. This smouldering heat is kept up for six months, during which the sulphur chamber is cleared four times, at the expiration of which period the ore is sufficiently roasted. The poorest of this, that is, such as contains from one and a fourth to two per cent. of metal, is then conveyed to the smelting-houses at Amlwch-port; the rest is sent to the company's furnaces at Swansea and Stanley near Liverpool. The greater part

of the kilns are very long, about six feet high; and the sulphur chambers are of the same length and height, connected by three flues, and on the same level with the kilns; four new ones, however, have been built at Almwch-port, by which much sulphur is preserved that would have been dissipated in the old kilns. The new ones are made like lime-kilns, with a contrivance to take out the roasted ore at the bottom, and thus keep up a perpetual fire. From the neck of the kiln branches off a single flue, which conveys the sulphur into a receiving chamber, built on the rock, so as to be on a level with the neck of the kiln, that is, above the ore.

The two smelting-houses, of which one belongs to each company, contain 31 reverberatory furnaces, the chimnies of which are 41 feet high; they are charged every five hours with 12 cwt. of ore, which yields 1-2 cwt. of rough copper, containing 50 per cent. of pure metal; the price of rough copper is about 2l. 10s. per cwt. The coals are procured from Swansea and Liverpool, a great part of which is Wigan slack. From experiment it appears, that though a ton of coals will reduce more ore than the same quantity of slack, yet, owing to the difference of price, the latter is, upon the whole, preferable; the prices of the two at Liverpool being—coals 8s. 6d. per ton—slack (small coal) 5s. per ditto.

The sulphat of copper, however, is the richest ore that the mine yields, containing about 50 per cent. of pure metal. This is found in solution at the bottom of the mine, whence it is pumped up into cisterns, like tanners' pits, about two feet deep: of these pits there are many ranges, each range communicating with a shallow pool of considerable extent. Into these cisterns are put cast-iron plates, and other damaged iron vessels procured from Coalbrook Dale; when the sulphuric acid enters into combination with the iron, letting fall the copper in the

form of a red sediment very slightly oxided. The cisterns are cleared once in a quarter of a year, when the sulphat of iron in solution is let off into the shallow pool, and the copper is taken to a kiln, well dried, and is then ready for exportation. The sulphat of iron remaining in the pool partly decomposes by spontaneous evaporation, and lets fall a yellow ochre, which is dried and sent to Liverpool and London.

The sulphur produced in the roasting, after being melted and refined, is cast into rolls and large cones and sent to London. The cones are used chiefly for the manufactory of gunpowder and sulphuric acid.

Green vitriol and alum are also made in small quantities by a separate company; but to these works strangers are not admitted.

The number of men employed by the two companies is 1200 miners, and about 90 smelters; the miners are paid by the piece, and earn in general from a shilling to twenty pence per day.

The depth of the mine in the lowest part is 50 fathoms, and the ore continues as plentiful as ever, and of a quality rather superior to that which lay near the surface.

With regard to the annual quantity of ore raised, little certain can be mentioned. The Parys mine has furnished from 5000 to 10,000 tons per quarter, exclusive of what is procured from the sulphat of copper in solution; and as the two mines employ nearly equal numbers of workmen, they probably afford about the same quantity of ore.

Adjoining to the smelting-houses is a rolling-mill, upon the same construction as malt-mills, for grinding the materials for fire bricks; these consist of fragments of old fire-bricks, with clunch (a kind of magnesian clay found in coal-pits) procured from near Bangor-ferry.

The port of Almwch is chiefly artificial, being cut out

of the rocks with much labour and expence, and is capable of containing 30 vessels of two hundred tons burthen; it is greatly exposed, and dangerous of access during high northerly winds, which drive a heavy sea up the neck of the harbour. The two companies employ 15 brigs from 100 to 150 tons burthen, besides sloops and other craft, all of which lie dry at low water.

The various articles, the produce of the mines, which are exported, are the following:

I. Coarse regulus of copper from the smelting-houses.
II. The richer copper ore roasted.
III. The dried precipitate of copper from the vitriol pits.
IV. Refined sulphur.
V. Ochre.
VI. Alum.
VII. Green vitriol.

The town of Amlwch, which about thirty years ago had no more than half a dozen houses in the whole parish, now supports a population of four or five thousand inhabitants; and was at present, being market day, thronged with miners and country people. After dinner we walked along the sea shore, climbing the steep slate rocks, whence the water below appeared of a beautiful green, and so transparent as to shew the shelving rocks to a great depth beneath. [*Aikin.* 1 *Nick. Jour.* 4*to.*

From Amluch I went to Beaumaris, a seaport in Anglesea; and from thence in a vessel laden with roasted copper ore to Liverpool. At Liverpool, I went to the copper works in the neighbourhood, and also to those at Warrington and Macclesfield in Cheshire; being desirous while I was about it, to trace the manufacture as far as I could. But those works were not easy of access, and I could obtain no precise information: what occurs to me on the subject at present, is contained in the following remarks:

1. Great caution is required in washing copper ore. It is true the earths and stones adhering to it should be got rid of; but the oxyds and the carbonats of copper intermixed, are apt to be washed away.

2. In roasting the sulphurets, the lumps should not exceed the size of a hen's egg: they are usually much larger. But the sulphur is not easily dissipated from the centre of a large lump, in which the roasting is no more than superficial.

3. In my opinion the roasting can never be perfect where the combustion is supplied by the sulphur alone. I can see no good reason why the common practice of mixing coal dust with the iron ores intended to be roasted, should not be applied to the copper ores.

4. If the sulphur contain arsenic it is not worth saving. This may be known by the garlic smell and the white fumes that accompany its combustion; and by its giving a white colour to a plate of pure clean copper held over it while it burns. If the sulphur be saved, I think it is best done by horizontal flues with doors in the side; the flues terminating in a chamber, which however must have an opening, to let out gasses and vapour.

5. I know of no furnace necessary either to the smelting, or the refining of the ore, other than the common cupola or reverberatory furnace. This furnace is so contrived that the ore is melted, not by coming into immediate contact with the fuel but by the reverberation of the flame upon it. The bottom of the furnace on which the ore is placed, is concave, shelving from the sides toward the middle, where a cavity (basin) is worked to contain the melted metal: it may be laid with free stone, or with fire brick set in loam, or made of Brasque (charcoal, burnt clay and soft clay, well mixed and beaten). The roof of the furnace is low and arched, resembling the roof of a baker's oven. The fire is placed at one end of the furnace upon an

iron grate, to the bottom of which the air has free access through the bars: at the other end, opposite the fire place, is a high perpendicular chimney. The direction of the flame, when all the apertures in the sides of the furnace are closed up, is necessarily determined by the stream of air which enters at the grate and takes its course toward the chimney, whose opening commences about the level, of the melted matter, and is proportionate to the draught required. In tending thither, it strikes upon the roof of the furnace, and being reverberated from thence upon the ore, soon melts it. 3 Watson, 274.

Schlutter has given plates of the Cupola furnace: and in Rees's Encyclopædia, new edition, (chemistry plate 1) there is a section of a cupola furnace with the application of a double bellows, which I think unnecessary, though common abroad. The common lead furnace, which is also the copper furnace, is well described in that work, article "Lead." It is this:

The reverberatory (cupola) furnace employed in smelting lead, is made on the same plan with those used in puddling iron (Cort's patent process.) differing however in size, and a few other particulars. The fire is made on one end, and the flame plays over the hearth, entering an oblique chimney at the other end, which terminates in a perpendicular one of considerable height. The length of the hearth from the place where the fire enters, to the chimney, is 11 feet. Two feet of this length next the fire, constitutes the throat of the furnace. The width of the same is four feet, and its depth about six inches. The length of the fire place is four feet, equal to the width of the throat; its width two feet, and depth three feet from the grate up to the throat of the furnace. The rest of the hearth is a concave surface, nine feet long, four and a half feet wide at the throat of the furnace, seven feet four inches wide at the distance of two feet from the hearth, seven

feet two inches in the middle of the hearth, five feet eleven inches at two feet distance from the chimney, and two feet ten inches at the place where the flame enters the chimney at two apertures each ten inches square. These apertures terminate in the oblique part of the chimney, the section of which is sixteen inches square, which communicates with the main chimney, the section of which is twenty inches square. Supposing a straight horizontal line drawn from the lower plane of the throat of the chimney to the opposite side of the furnace, the lowest part of the concave hearth which is in the middle of this cavity, is nineteen inches below this line, the roof of the furnace being seventeen inches above the same line.

On each side of the furnace, are three openings, each about ten inches square for lead, but larger for copper; provided with iron doors to be removed as occasion requires. They are arranged at equal distances from each other, between the commencement of the hollow hearth, and the entrance into the chimney. The lower part of these apertures is on a level with the horizontal line above alluded to: being for the purpose of stirring and raking the ore, &c. Besides the larger openings, there are two small apertures, one below the large middle opening, and nearly on a level with the bottom of the furnace; the other under that opening which is nearest to the chimney, at some distance above the first aperture. The first, is a tap hole for the metal; the second for the scoriæ. The ore is introduced by a vessel in the shape of a hopper, placed in the roof of the furnace.

The preceding descriptions seem to me clear enough to render a plate unnecessary.

6. The smelting must be continued and repeated, till the black copper appears of its proper colour and fit for the refining; and most of the mixed metals are calcined and fused with the slag. I do not know a finer road, than

ten or twelve miles between Liverpool and Warrington, made of the slag of copper works.

7. The theory of cleansing copper from its impure mixtures, is, that it is less easily oxydable than iron, zinc, antimony or the other semi-metals. Sometimes iron is added to promote the separation of the sulphur: sometimes lead to promote the oxydation of the more oxydable metals. I cannot say in what proportions, or under what circumstances, because this must depend on the mixture to be determined by the previous analysis of the ore. Indeed, I distinctly remember, endeavouring to ascertain the mixtures and the circumstances, but without effect. It either was, or was pretended to be a great secret. Every manufactury in England, is a repository of secrets. I suspect the process would be aided by manganese.

8. I am under no hesitation in saying, that the intermixture of charcoal dust, or coak dust, with the ore both in the previous roasting, and in the furnace, and making a thin coating at the bottom of the hearth and basin, of the same material, would greatly promote the fusion and purification of the matt. Toward the last stage of the process of refining, when the oxydable metals are to be oxyded, there would be no difficulty, if need required, to introduce a current of air over the surface of the melted metal, as it appears to me. But I have not skill in the subject to do more than suggest.

Copper is an article so necessary to us at present for sheathing ships, for making distilling vessels, for vessels used for culinary purposes, for plated ware, for coin, &c. &c. that I hardly know any manufacture of such importance, after that of iron: and yet we have no smelting work for copper, or any copper mine worked in the United States. Nor shall we have, till steam engines to draw off the water and to raise the ore, become common. I would gladly undertake the article *mining*, and perhaps I

may yet venture upon it; but I have no experience except for about six months in a coal mine of my own; and I am afraid of going out of my depth.

I have said, that copper is of great moment for sheathing ships, but, I think the use of *coal-tar* will go a great way to preserve our vessels without it. The ship builders, brought it into disrepute in England for this very reason; it preserved the ships too well.

I have said that copper is of great moment for *distilling vessels;* when I come to the article "distillery," I shall make this assertion of mine very problematical: probably in the next number.

I have said that copper is of great moment for *culinary vessels;* but iron, or iron coated with Hicklin's porcelain, or with Dr. Bollman's platina, may by and by supersede copper.

Having now reduced (so far as my knowledge extends) the copper into a pure metalline state, I proceed to enumerate its properties when in that state.

Properties of Pure Copper. It is in colour of a yellowish red: it is ductile and malleable: it is harder than silver: it breaks with a hackly fracture: it is tougher than any other metal, excepting iron: it emits, when rubbed, a disagreeable smell: it has a nauseous taste: it fuses at low white heat: before it melts, it exhibits prismatic colours on its surface: it burns with a red flame edged with green when fused exposed to the air: it is easily oxyded when in fusion: it is easily tarnished by common exposure to the air: when so exposed, it combines with oxygen and carbonic acid, turning green: it unites to oxygen, sulphur, to phosphorus, to oils, to all the acids and alkalies. The specific gravity of the purest or Japonese copper is 9,: of Swedish copper 8,89: of common copper 8,6.

Preparation of sulphat of Copper, or blue vitriol of commerce.

The *sulphat* of copper, as an article of importance in several of the arts, merits our attention. For the purposes of commerce this salt has been prepared by different methods, which are,

1st. The vitriolization of the native *sulphurets* of copper, (copper pyrites).

2dly. The *formation* and *vitriolization* of artificial *sulphurets* of copper.

3dly. The evaporation of cupreous waters, and

4thly. By dissolving metallic copper in the sulphuric acid.

The first mode is practised on a large scale, particularly in Germany. That the sulphurets of copper are more difficult to vitriolize than those of iron is evident from the circumstance of the latter frequently undergoing a decomposition in consequence of exposure to atmospheric air; on this account some particular treatment is required to fit those of copper for our present purpose. Copper pyrites are broken into small pieces, alternate strata are formed with these and combustible matter; when the heap is finished it is set fire to; the fire should be moderate, and long continued; by this means the operation will be more easily managed, and more salt will be formed by the process. This roating generally lasts for 24 hours, the matter remaining is, whilst hot, thrown into tubs containing water: here it continues during 48 hours: the water should be agitated whilst it is acting on the roasted ore. The ore is now taken from the water and is roasted a second time, and is treated with water as before. We continue throwing roasted ore into the water until this last receives a fine blue colour. The solution must then be sufficiently evaporated in boilers of lead or

copper pans. On being allowed to cool the salt will crystallize.

In some places they perform the roasting during twelve hours in a reverberatory furnace.

In some countries pyrites which contain but a small quantity of copper are made use of to obtain both the sulphur and the sulphat or blue vitriol; for this purpose the ore is broken into very small pieces, earthen vessels in the form of tubes are charged with these, and then they are exposed to heat; the sulphur comes over and is received in iron vessels, connected with the earthen ones above-mentioned; the residuum is treated for *vitriol* in the manner recommended for roasted pyrites.

The second method is employed in France in the following manner: plates of copper are steeped in water, they are then withdrawn and whilst wet, pulverized sulphur is strewed over them; thus prepared they are exposed in an oven heated to redness; after remaining for some time in this oven they are withdrawn, and whilst hot they are thrown into tubs which contain water. These operations are repeated until the whole of the copper is vitriolized; when the water is sufficiently impregnated with salt, it is evaporated, &c. as above-mentioned.

According to Newmann, cuttings or waste pieces of copper are stratified and cemented with sulphur. The cover of the cementing pot is perforated with one or two small holes, and the cementation is continued with a gentle fire till the inflammable part of the sulphur is consumed. The matter is then boiled in water, and the liquor, after due evaporation, is set to crystallize. Such parts of the copper as remain uncorroded, are again treated in the manner just described.

Chaptal fused 2*lbs.* of sulphur in a crucible heated to redness: the crucible was constantly kept in the midst of the burning coals; in this situation 2*lbs.* of sheet copper

were put into it; in a very short time after, a considerable flame took place, and the copper became red; when the flame ceased, the crucible was removed from the fire; after cooling, the copper was very brittle, of a fine dark red colour, and presented a silky striated fracture; it weighed 2*lbs.* 10*oz.* The sulphuret thus formed, was divided into two equal parts, one of these was occasionally moistened with pure water, and the other with water acidulated with the sulphuric acid. The first part did not effloresce; notwithstanding every care during thirteen months, there was not the least appearance of *vitriolization:* the second parcel effloresced, and by occasionally moistening it with the acidulated water, nearly 5*lbs.* of the sulphat of copper was obtained from it.

It is said that the quantity of sulphur may be lessened by projecting it on the copper heated to redness.

When the third method is made use of, wells are dug in proper situations in such mines as are charged with cupreous waters, into these the waters are conducted from different parts of the mine; it is only necessary to evaporate them, and to set them by to crystallize.

The fourth method will certainly furnish a very pure salt. As metallic copper is insoluble in the sulphuric acid in the cold, a boiling heat is made use of by some to effect the combination. Other manufacturers oxyde the copper by exposing it to heat before they place it in the acid. Or dissolve the oxyd of copper at once in sulphuric acid.

Sometimes the sulphat of copper is contaminated with a mixture of the sulphat of iron (copperas.) This circumstance will make it unfit for most purposes. The presence of this last is ascertained by dissolving a portion of the suspected salt in water, and adding the infusion of galls to it; if there be any iron in the solution a black colour will be produced.

Sulphat of copper has a very strong, styptic, somewhat acidulous, and excessively nauseous taste. It is soluble in about four times its weight of water. When dried at a heat not exceeding that of boiling water, it loses, according to Proust, about 36 *per cent.* which is mere water, after which the residue, which is a white pulverulent mass, is again soluble and crystallizable, as at first. But if it is calcined with a strong white heat, the acid itself is expelled without undergoing decomposition, and at length there only remains black oxyd of copper, in the proportion of 32 *per cent.* of the original crystallized salt. Hence 100 parts of sulphat of copper consist, according to Proust, of

Copper 25.6 Oxygen 6.4	forming black oxyd	32
	Sulphuric acid	32
	Water	36
		100

Bergmann's analysis of this salt nearly agrees with that of Proust in the proportion of copper (26 *per cent.*); but of the other ingredients he reckons 28 of water, and 46 of acid. [*Rees's Encyc. Art. Copper.*

Verdigris.—I know of no more authentic account than Chaptal's dissertation on the subject who has had more opportunities of information than any person else who has treated on this manufacture. I would premise, however, that I can see no reason why common blue vitriol precipitated by pearl ash, will not answer all the purposes of verdigris. They are both carbonats of copper. In the dying of hats, I am persuaded that much of the verdigris is wasted, and that blue vitriol would be an advantageous substitute; for blue vitriol and logwood give a blue, which though very fugitive on cotton, stands tolerably well when mixed with the black dye of the hatters.

Observations on the Manufacture of the Acetite of Copper or Verdigris, Verdet, &c.

The acetite of copper is one of the preparations of that metal most frequently used in the arts. It is not only one of the principal resources of painting, but upon many occasions is employed with great advantage in dying. Almost all the oxyds of copper obtained by the action of saline substances have a blue colour, more or less inclining to green; and almost all the neutral salts corrode the metal, and produce that oxyde which is called verdigris. It is sufficient to bring them into contact with the copper, or to immerse the metallic plates in a saline solution, and afterwards to expose them to the air to dry.

Those acids which oxydate the copper by their decomposition, produce an effect like that of neutral salts. The oxyde is of a soft blueish-green colour; their action is so speedy, that if the copper be exposed to the vapour of them for some minutes, its surface will be immediately oxydated. The oxygenated muriatic acid produces that effect as well as the vapour of the nitric acid, and even those of the sulphuric acid. A phenomenon which cannot escape the eye of an observer, is, that the oxydes of copper obtained by fire, are very different from those produced by the decomposition of acids on that metal. The colour of them is grey, instead of being green; and when the calcination is continued a long time at a violent heat, they may be concentrated to a red oxyde of a blood colour. This phenomenon was observed by Kunckle in his Chemical Laboratory.

Saline substances are not the only ones capable of oxydating copper green. All oils and fat matters produce the same effect. Even water, when left for a considerable time in copper vessels, causes an oxydation. But what will appear very extraordinary, is, that the greater part of these substances have no sensible effect upon cop-

per, except when cold. Those salts even which corrode that metal when left at rest in vessels, do not attack it in so sensible a manner when in a state of ebullition.

Of all the preparations of copper by oxydation, there is none more valuable than that made by vinegar. All the verdigris used in commerce is prepared by that acid, and it is at Montpellier in particular and in the neighbourhood, that the manufactories of it are established. In the Memoirs of the Academy of Paris for 1750 and 1753, may be seen a very exact description of the process then followed at Montpellier for making verdigris; but as that process has been much improved, and as at present the husks of grapes are employed instead of the stalks, a method far more economical, since wine is no longer used, the following account of the manner of manufacturing verdigris, as now practised, may be of utility to the public.

The first materials used for this purpose are copper and the husks or skins of grapes left after the last pressing. The copper employed was formerly all imported from Sweden; but at present it is brought from different foundries established at Saint Bel, Lyons, Avignon, Bedarieux, Montpellier, &c. It is in round plates half a line in thickness, and from twenty to twenty-five inches in diameter. Each plate at Montpellier is divided into twenty-five laminæ, forming almost all oblong squares of from four to six inches in length, three in breadth, and weighing about four ounces. They are beat separately with the hammer on an anvil to smooth their faces, and to give the copper the necessary consistence. Without this precaution it would exfoliate, and it would be more difficult to scrape the surface in order to detach the oxydated crust. Besides this, scales of pure metal would be taken off, which would hasten the consumption of the copper.

The husks of grapes, known at Montpellier under the

name of *racque*, were formerly thrown on the dung-hill after the poultry had picked out the small stones contained in them. At present they are preserved for making verdigris, and sold at the rate of from fifteen to twenty livres per *muid*. The preparation of them is as follows: After the vintage is finished, the husks are subjected to the press in order to extract all the wine with which they may be impregnated, and they are then put into vats, where they are pressed down with the feet to fill up all the vacuities and render the mass as compact as possible. The coverings of these vats are carefully fastened down, and they are preserved for use in a dry cool place.

These husks are not always of the same quality: when the grapes contain little of the saccharine matter, when the season has been rainy, the fermentation incomplete, or when the wine is not generous, the husks are attended with several faults. 1. They are difficult to be preserved, and there is great danger of their soon being spoilt. 2. They produce very little effect, cannot be easily heated, send forth very little of the acetous odour, and make the plates of copper sweat without shewing efflorescence on their surface. Independently of the nature of the grapes and the state of the wine, the quality of the husks varies also according as they have been expressed with more or less care. Husks which have not been much pressed, produce a far greater effect than those which have been dried. To explain their different effects, it will be sufficient to observe that their action is proportioned to the quantity of wine they retain, as it is that liquor alone which can pass to the state of vinegar. When the husks therefore are destined for a verdigris manufactory, care must be taken to express them only weakly, in order to preserve more of their acidifiable principle.

When a sufficient quantity of copper and of husks has been provided, nothing remains but to proceed to the ope-

rations, which are generally performed in cellars. They may be performed also on a ground floor if it be somewhat damp, if the temperature be subject to little variation, and if there be not too much light. The first operation is to make the husks ferment, which is called *avina*. For that purpose one of the vats is opened, and the husks are put into two others of equal size, taking care to expose them as little as possible to the air, and not to compress them. One vat full of husks ought to fill two, and to occupy a double space after this operation. In some manufactories the husks contained in a vat are distributed into twenty or twenty-five earthen vessels or jars called *oules*, and which are generally sixteen inches in height, fourteen in diameter at the belly, and about twelve at the mouth. When the husks have been put into these vessels, they are covered by putting the lid merely on the opening without pressing it down. The covers are of straw, and made for that purpose. In this state the husks soon heat; and this change may be known by thrusting the hand into them, and by the sour smell which they begin to exhale. The fermentation first takes place at the bottom of the vessel, and gradually ascending extends itself to the whole mass. It proceeds to 30 or 35 degrees of Reaumur.

At the end of three or four days the heat decreases, and at length ceases entirely; and as the manufacturers apprehend the loss of a portion of the vinegar by the natural effect of a heat too much prolonged, they take care after three days fermentation to remove the husks from the fermenting vessels, in order that they may sooner cool.

Those who employ vats remove them into jars, and those who use jars put them into others. Besides the loss of the acetous spirit, too great heat inclines the mass at the bottom of the vessel to become mouldy, which renders it unfit for making verdigris. Some manufactu-

rers, to increase the effect of the husks, form them into heaps, which they besprinkle with generous wine before they bring them to ferment.

The fermentation does not always take place at the same time, nor with the same energy. Sometimes it commences in twenty-four hours, and sometimes it has not begun at the end of three weeks. The heat sometimes will rise to such a height that the hand cannot be kept in the mass, and that the acetous odour is so strong that one can hardly approach the vessels; while at others the heat is hardly sensible, and soon vanishes. There are even instances of the husks becoming putrid and mouldy without turning acid. The fermentation is assisted and promoted by raising the heat of the place by means of chafing-dishes, by covering the vessels with cloths, by shutting the doors, and by airing the mass with more care. The differences in the fermentation depend, 1. On the temperature of the air: in summer the fermentation is speedier. 2. On the nature of the husks: those which arise from very saccharine grapes heat more easily. 3. On the volume of the mass: a larger mass ferments sooner, and with more strength, than a small one. 4. On the contact of the air: the best aired husks ferment best.

At the same time that the husks are made to ferment, a preliminary preparation called *desafouga* is given to the plates of copper which are used for the first time. This operation is not employed for those which have been already used, and consists in dissolving verdigris in water in an earthen vessel, and rubbing over each plate with a piece of coarse linen dipped in this solution. The plates are then immediately placed close to each other, and left in that manner to dry. Sometimes the plates are only laid on the top of the fermented husks, or placed under those which have been already used for causing the copper to oxydate. It has been observed, that when the ope-

ration called *desafouga* has not been employed, the plates grow black at the first operation, instead of becoming green.

When the plates are thus prepared, and the husks have been brought to ferment, the workmen try whether the latter are proper for the process, by placing under them a plate of copper, and leaving it buried there for twenty-four hours. If the plate of copper, after this period, is found covered with a smooth green crust, in such a manner that none of the metal appears, they are then thought fit for being disposed in layers with the copper. On the other hand, if drops of water are observed on the surface of the plates, the plates are said to *sweat*, and it is concluded that the heat of the husks has not sufficiently subsided. They consequently defer making another trial till the next day. When they are assured that the husks are in a proper state, they form them into layers in the following manner:

The plates are all put into a box, which, instead of having a bottom, is divided in the middle by a wooden grate. The plates disposed on this grate are so strongly heated by a chafing-dish placed under them, that the woman employed in this labour is sometimes obliged to take them up with a cloth, in order that she may not burn her hands. As soon as they have acquired that heat, they are put into the jars in layers with the husks. Each jar is then closed with a covering of straw, and left to oxydate. This period is called *coua*, to hatch. Thirty or forty pounds of copper, more or less according to the thickness of the plates, are put into each jar. At the end of ten, twelve, fifteen, or twenty days, the jar is opened; and if the husks are white, it is time to take out the plates. The crystals are then seen detached, and of a silky appearance on the surface. The husks are thrown back, and the plates are put in what is called *relai*. For that purpose

they are immediately deposited in a corner of the cellar on sticks ranged on the floor. They are placed in an upright position, one leaning against the other; and at the end of two or three days they are moistened, by taking them up in handfuls and immersing them in water in earthen pans. They are deposited quite wet in their former position, and left there for seven or eight days; after which they are once or twice immersed again. This immersion and drying are renewed six or eight times, every seven or eight days. As the plates formerly were put into wine, these immersions were called *one wine*, *two wines*, *three wines*, according to the number of times. By this process the plates swell up, the green is nourished, and a coat of verdigris is formed on all their surfaces, which may be easily detached by scraping them with a knife.

Each jar furnishes five or six pounds of verdigris at each operation. It is then called fresh verdigris, moist verdigris, &c. This verdigris is sold in that state by the manufacturers to people who dry it for foreign exportation. In this first state it is only a paste, which is carefully pounded in large wooden troughs, and then put into bags of white leather, a foot in height and ten inches in diameter. These bags are exposed to the air or the sun, and are left in that state till the verdigris has acquired the proper degree of dryness. By this operation it decreases about fifty per cent. more or less according to its primitive state. It is said to stand proof by the knife, when the point of that instrument pushed against a cake of verdigris through the skin cannot penetrate it.

The plates of copper which have been already used are again employed for the same operation, till they are almost completely consumed. Instead of heating them artificially, as above mentioned, they are sometimes exposed only to the sun. The same plates will serve sometimes for ten years, but they are often worn out in two or

three. This, however, depends on the quality of the copper. That which is extremely smooth, well beat, and very compact, is always most esteemed.

Formerly moist verdigris could not be sold till its quality had been previously ascertained; and for that purpose it was carried to a public ware-house, where it was sold after that point had been determined.

By comparing this process with that described by Montet, it will be found that the changes introduced are much in favour of the new. Formerly the workmen took the stalks of the grapes dried in the sun, and began by immersing them for eight days in *vinasse* (the residuum of the distillation of wine for making brandy). They then suffered the moisture to drain off through a basket, after which they put about four pounds into a jar, and poured over them three or four pints of wine. The stalks were made to imbibe a large portion of the wine, by stirring them strongly with the hand; the jar was then covered, and the stalks were suffered to ferment. The fermentation commenced sooner or later, according to the nature of the wine and the temperature of the air. But after it had once begun, the wine became turbid, and exhaled a strong odour of vinegar. At length the heat decreased, and the stalks were then taken out and the wine was drawn off. When the stalks were a little drained, they were disposed in layers with the plates of copper, and the operation was continued in the same manner as with the husks. When the plates were taken from the jars to be put in *relai*, instead of immersing them in pure water, as is done at present, they were moistened three or four times with sour wine, which was called giving them three or four wines.

It may be easily seen that there is a great saving in the process followed at present, since the manufacturers no longer use wine, which enhanced the price of the verdigris.

Some have condemned, in the new process, the practice of using the copper too soon; but this objection fell to the ground, when it was observed that the verdigris obtained was in proportion to the copper corroded; and what proves that this method is more advantageous, is, that all the manufacturers have abandoned the old method and adopted the new.* [*4th Phil. Mag.* 71.

Preparation of Crystallized Acetite of Copper: Crystalli veneris.

This is called in the colour shops distilled verdigris. Chaptal has given the process as follows:

Crystals of Venus were for a long time manufactured in Holland, but at present they are manufactured at Montpellier, with a degree of perfection which renders them preferable to those of any other country. The process most generally employed consists in dissolving verdigris in vinegar, and evaporating the solution to a pellicle to obtain the crystals. The vinegar used is nothing else than sour *vinasse* (spoilt wine) distilled. In every manufactory there is therefore an alembic, in which this weak kind of vinegar is continually distilled.

This distilled vinegar is put into a kettle, where it is boiled on the verdigris. After saturation the solution is left to clarify, and then poured into another kettle of copper, where it is evaporated to a pellicle. Sticks are then immersed into it, and by means of some pack-thread are tied to wooden bars which rest on the edge of the kettle. These sticks are about a foot long, and are split crosswise nearly two inches at the end, so that they open into four branches, kept at about the distance of an inch from each other by small pegs. The crystals adhere to these

* There are no large manufactories of verdigris at Montpellier; but each family makes a certain quantity, and the operations are in general performed by women.

sticks, and cover them entirely, forming themselves into groups or clusters, which present on all sides perfect rhombs of a very lively dark blue colour. Each cluster weighs from five to six pounds. These crystals, when broken, exhibit on their fracture a brilliant agreeable green, inclining a little to blue.

Three pounds of moist verdigris are necessary to make a pound of crystals. The indissolved residuum is rejected as useless. Analysis, however, having proved to me that a great deal of copper in a metallic state, or weakly oxydated, still exists in it, I disposed boards in the form of a stage around the manufactory of C. Durand, and, forming strata of about two inches in thickness with these remains, I soon saw them covered with an efflorescence of verdigris. I took care to moisten them from time to time with vinegar, to dissolve the verdigris as soon as a sufficiently strong efflorescence was formed, and they were again disposed in strata to proceed as before, in order that I might derive as much advantage from the residuum as I should find convenient.

There are some manufactories of the crystals of Venus where the verdigris is prepared by means of vinegar distilled according to the method followed at Grenoble, which is well understood. All the operations tend to the same end, which is the solution of the copper in the acetous acid; and the purity of the materials renders it certain that there will be no residuum or loss. But however simple may be the process for manufacturing crystallized verdigris, the high price at which it is sold makes it much to be wished that it could still be rendered more so. I made some experiments for that purpose; but at present I shall confine myself to a short view of my results. We must set out from the principle, that the acetous acid does not attack copper in the state of a metal, and that it cannot effect a solution of it but when re-

duced to an oxyd. The question then will be to discover the means of oxydating it in an economical manner.

1st, I exposed the plates of copper to the gazeous emanations of the oxygenated muriatic acid in large glass receivers, connected together in the manner of adoptors, to which I fitted a retort from which the acid was disengaged.

2d, I took a large earthen jar of Provence, well glazed, capable of containing two hundred (French) pints of water, buried it one half in a stratum of very warm dung in full decomposition, and having put some manganese in the bottom of it, and adapted to it a straight glass tube, which reached from the mouth to the bottom, I filled the jar with plates of copper slightly rolled, in order that they might not touch each other but in some points. I then made to pass into the bottom of the jar, by means of the tube, the necessary quantity of the muriatic acid, and immediately closed the upper aperture with a luted covering. Two days after these plates were entirely crusted over with a greenish oxyd, which detached itself in dust and in scales: I separated of it two pounds ten ounces. This oxyd, less lively than that of the common verdigris, is soluble in vinegar: and this method may then be employed, with some advantage, to form the acetat of copper; but it cannot supply the place of the acetous verdigris either in painting or dyeing.

3d, I formed sulphat of copper by pouring, upon plates of copper brought to a red heat in a crucible, about a third in weight of pounded sulphur. This sulphur, exceedingly friable, pulverised and exposed to a pretty violent heat for four or five hours, left a grey powder, easily attacked by the acetous acid. That which I digested at a heat above a gentle temperature, gave, by evaporation, a considerable quantity of very blue and beautiful crystals of acetat of copper, and a stratum of true sulphat of copper of a pale blue and without crystals.

4th, I saturated distilled acetous acid with oxygenated muriatic acid gas. This acid, digested cold on the copper, dissolved it in part; but it formed a beautiful micaceous scaly white, which had no relation with the acetat. Copper exposed to the vapour of this acetous acid, saturated with oxygenated muriatic acid gas, becomes covered with very brilliant small crystals of a bright-blue colour, some of which are transparent and white. These crystals presented long square pyramids, effloresced in the air, and had none of the characters of the acetat of copper.

5th, The acetous acid, distilled several times on the oxyd of manganese, attacks copper and dissolves it, but too weakly and in too small quantity for me to recommend this method.

6th, The acetite of lead poured upon a solution of the sulphat of copper immediately produces a decomposition from which there results sulphat of lead, which precipitates itself in a little time; and acetat of copper, which remains in solution. By decanting the latter, and evaporating it to a pellicle in a copper kettle, you will obtain beautiful crystals of Venus. If you wash well the sulphat of lead, and prepare it to be employed in painting, as white lead, this last process may become very advantageous.

Crystallized verdigris is in great request for painting and varnishing, to which it supplies lively and durable colours. Chemists obtain from it by distillation that acid, the smell of which is very penetrating, called *radical vinegar*, and also *acetite acid*.—4 *Philos. Mag.* 171.

Preparation of acetic acid or radical vinegar. This used to be prepared in large quantities for sale, as an antiseptic, and aromatic, as well as a cephalic medicine, (to be smelt at) by Mr. Henry, father to Dr. William Henry, of Manchester. I do not know, therefore, that any bet-

ter account can be given of its preparation than Dr. Henry's own. For my own part, I strongly suspect that in the large way, common strong vinegar is saturated with whiting: filtered, reduced to a dry mass, and distilled with vitriolic acid. The retort will contain sulphat of lime. The vinegar must be re-distilled with a moderate heat.

"When this salt, acetite of potass is distilled, with half its weight of sulphuric acid, the vegetable acid is expelled in a very concentrated form, mixed with sulphurous acid. Digestion with a small portion of manganese, and subsequent distillation, affords it pure. It may be obtained, also, by distilling equal parts of acetate of lead and sulphat of copper. Or

The crystallized acetate of copper, contained in a glass retort, which may be nearly filled with the salt, may be submitted to distillation in a sand-heat. The acid that comes over has a green colour, and requires to be rectified by a second distillation. Its specific gravity then varies from 1056 to 1080. If the products be reserved in separate portions, it has been observed by M. M. Derosne, that those which are obtained towards the close, though specifically lighter than the earlier ones, are still more powerfully acid, assuming, as the test of their strength, the quantity of alkali which they are capable of saturating. The last products, it was found also, when submitted to distillation, yield a liquid which has even less specific gravity than water. This liquid may be obtained, in a still more perfect state, by saturating the latter portions of acetic acid with caustic and solid potash; the acetate of potash precipitates; and a fluid swims above it, which may be rectified by distillation at a gentle heat. It is perfectly limpid; has a penetrating taste; is lighter than alcohol; evaporates rapidly with the production of cold when poured upon the hand; and is highly inflam-

mable. It does not redden litmus. Excepting that it is miscible, in any proportion, with water, it has all the qualities of ether, and like that fluid has the power of decomposing the nitromuriate of gold. M. M. Derosne have proposed for it the name of *pyro-acetic ether*. Its production, they observe, is confined to the latter stages in the distillation of acetate of copper, and is owing, they suppose, not to any modification of alcohol, but to changes in the arrangement of the elements of the salt.

These observations are confirmed by the subsequent ones of M. Mollerat. Examining two portions of acetic acid, which had precisely the same specific gravity (*viz.* 1063), he found that the one contained 87 *per cent.* of real acid, and the other only 41. The first he is disposed to consider as the strongest acetic acid that can be procured. It may be distilled at a very moderate heat with great rapidity, and without entering into ebullition. To this acid, having the specific gravity 1063 (and of which 100 grains required for saturation 250 of sub-carbonate of soda), he gradually added water, and found, though water is lighter than the acid, yet that the density of the mixture increased till it became 1079. From this point, the additions of water occasioned a regular diminution of specific gravity. Mr. Chenevix has since observed the same anomally, in the acid produced from acetate of silver.

Acetic acid, thus prepared, has several remarkable properties. Its smell is extremely pungent, and it raises a blister when applied to the skin for a sufficient length of time. When heated in a silver spoon over a lamp, its vapour may be set on fire. At the temperature of about 38° Fahrenheit it becomes solid and shoots into beautiful crystals, which again liquefy at 40°. It appears not to be easily destructible by heat; for Mr. Chenevix transmitted it five times through a red-hot porcelain tube, with the effect of only a partial decomposition."

2 *Hen. Ch.* 220.

Scheele's Green: Arseniat of Copper. Dissolve in 45 parts of boiling water, 2 pounds by weight of pounded blue vitriol or sulphat of copper. In 10 parts by weight of boiling water dissolve 2 parts of potash and 1 1-2 part of white arsenic, boiling it, till the latter is dissolved. Then make up the liquor 45 parts by adding boiling water (taking a wine pint as 16 ounces). Add the first solution while hot, gradually to the last. A precipitate will fall down of a fine green colour, which is arseniat of copper. Wash it well and dry it. It is a good pigment both as an oil and water colour.

If you want it diluted, add to your solution of blue vitriol one part or more, by weight of alum, in which case you must encrease your potash one half part for each part of alum.

This is the common green used by the paper stainers.

Brunswick green. This is said to be made by stratifying shavings of copper with ground argol or tartar made into a paste, which I have no doubt would produce a good colour. But M. Kastelyn's receipt is as follows: Dissolve three parts by weight of sal ammoniac in water: put into a close or covered vessel two parts by weight of copper shavings, sprinkle them from time to time with the solution of sal ammoniac. The green colour produced will weigh six parts.

Verditer, is made in three or four ways. 1st, By precipitating copper from a solution of blue vitriol or sulphat of copper, by means of a clear solution of pearl or potash. About half a part of potash by weight, or 3 fourths of a part of pearl ash, will throw down the copper of one part of blue vitriol. This will form a carbonat of copper, or an imitation of verdigris equally good in all particulars.

2dly, By precipitating a solution of blue vitriol with whiting, in which case, the copper thrown down is dilut-

ed and enfeebled in colour by the addition of sulphat of lime, formed by the union of the lime of the whiting to the sulphuric acid of the blue vitriol. This is what is called Sanders' blue: a corruption I presume of *cendres blues.*

3dly, When the refiners dissolve together in aqua fortis a mixture of copper and silver, they separate the silver by adding a solution of common salt; the acid of common salt unites with the silver, and the alkali of common salt unites with that portion of the aqua fortis which held the silver in solution. The liquor now contains nitrat of copper and nitrat of soda. The copper may be thrown down, either by a solution of pearl or potash, or by whiting. In this latter case, the whiting does not mix with and contaminate the colour of the precipitate, as the nitrat of lime is soluble in water.

These precipitates when washed, form the various shades of green and blue Verditer, used by the paper stainers.

In all these cases, the precipitate is a carbonat of copper: different shades may also be procured, by using pure lime, and pure or caustic potash. (Soap boiler's Ley.)

Mr Hatchett's brown prussiat of copper.

On the utility of Prussiat of Copper as a pigment. By Charles Hatchett, Esq. F. R. S.

The accidental discovery made by Diesbach of the pigment called Berlin or Prussian blue, about the year 1710, and which afterwards was published by Woodward in the Philosophical Transactions for 1724, was soon adopted by artists and manufacturers, so that in a short time the great utility of this colour was completely established: it is therefore remarkable, that but little attention has been subsequently paid to the colorific properties of the other metallic prussiates.

The experiments made by Mr. Brown with the prussic lixivium on various metallic solutions do not merit particular attention, as the results evidently show that a very large proportion of the alkali remained unsaturated with prussic acid, and thus the effects appeared different when the lixivium was prepared with blood or with muscle.

Bergman has, however, more accurately observed the properties of metallic precipitates, (Opuscula, tom. ii. p. 385), and especially notices the various colours of the prussiates; but neither he nor any other chemist, as far as I am acquainted, has pointed out to artists the utility of prussiat of copper as a pigment. During some late experiments, I was much struck with the beauty of this precipitate, and was therefore induced to make several trials of it as a paint: the results exceeded my most sanguine expectations. I afterwards prepared a large quantity, which at my request several gentlemen (particularly B. West, Esq. P. R. A., John Trumbull, Esq., and Sir H. C. Englefield,) were so obliging as to try in oil, and in water; and I have had the satisfaction to learn, that in beauty and intensity it surpasses every brown paint now in use, with the additional advantage, that, by reason of its purple tint, it forms with white various shades of bloom or lilac colour, which do not appear liable to fade like those which are formed by means of lake.

The prussiates obtained from acetite, sulphate, nitrate, and muriate of copper, are all very beautiful; but the finest and deepest colour is afforded by the muriate. I have found also that prussiate of lime can be better depended upon for this purpose than prussiate of potash. The best mode, therefore, of forming this pigment, is to take green muriate of copper, diluted with about ten parts of distilled or rain water, and to pour in prussiate of lime until the whole is precipitated: the prussiate of copper is then to be well washed with cold water on the filter, and to be dried without heat.—14 *Phil. Mag.* 359.

This colour seems to me to have been first pointed out by Dr. Bancroft in page 217 of his experimental researches on permanent colours, first edition.

Of the Alloys of Copper. Brass. Orichalchum. The orichalchum of the ancients, was of three kinds: the mountain copper mentioned by Hesiod. The Corinthian brass, a mixture of various metals from the melting together of the statues, at the taking of Corinth. Lastly, Brass, made by fusing copper with cadmia or calamine. That, latterly, the orichalchum of the ancients was brass, is sufficiently made out by the Bishop of Landaff in his treatise on orichalchum in the second volume of the Manchester Transactions, and in his Essays, vol. 4. His account of the modern process for making brass is as follows:

The method of making ordinary brass I will now describe.

Copper in thin plates, or, which is better, copper reduced (by being poured, when melted, into water) into grains of the size of large shot is mixed with calamine and charcoal, both in powder, and exposed in a melting pot for several hours to a fire not quite strong enough to melt the copper, but sufficient for uniting the metallic earth of the calamine to the phlogiston of the coal; this union forms a metallic substance, which penetrates the copper contiguous to it, changing its colour from red to yellow, and augmenting its weight in a great proportion. The greater the surface of a definite weight of copper, the more space has the metallic vapour of the calamine to attach itself to; and this is the reason that the copper is granulated, and that it is kept from melting and running into a mass at the bottom of the vessel, till near the end of the operation, when the heat is increased for that purpose.

The German brass-makers, in the time of *Erckern*, used to mix 64 pounds of small pieces of copper with 46 pounds of calamine and charcoal, and from this mixture

they generally obtained 90 pounds of brass.* Cramer recommends 3 parts of powdered calamine to be mixed with an equal weight of charcoal dust and two parts of copper, and says, that the brass obtained by the process exceeds the weight of the copper by a fourth, or even a third part of its weight.† At most of our English brass-works they use 45 pounds of copper to 60 pounds of calamine for making ingot brass, and they seldom obtain less than sixty or more than seventy pounds of brass; at Holywell they reckon the medium product to be 68: and hence a ton of copper, by this operation, becomes rather more than a ton and an half of brass. This is a larger increase of weight in the copper, than is observed in any of the foreign manufactories that I have ever read of, and it may be attributed to two causes, to the superior excellence of our calamine, and to our using *granulated* copper. Postlethwayte, in his Commercial Dictionary, attributes the difference in the increase of weight acquired by the brass to the different natures of the coppers which are used, "there is an increase of 48 or 50 pounds in an hundred, if copper of Hungary or Sweden be used; that of Norway yields but 38, and that of Italy but 20." When they make brass which is to be cast into plates, from which pans and kettles are to be made, and wire is to be drawn, they use calamine of the finest sort, and in a greater proportion than when common brass is made, generally 56 pounds of calamine to 34 of copper. Old brass which has been frequently exposed to the action of fire, when mixed with the copper and calamine in the making of brass, renders the brass far more ductile and fitter for the making of fine wire than it would be without it; but the German brass, particularly that made at *Nuremberg*,

* Fleta Minor, by Sir J. Pettus, P. 286. Newman gives the same proportions, P. 65.

† Cram. Ars Doc. Vol. II. p. 246.

is, when drawn into wire, said to be preferable to any made in England for musical instruments. If this preference be real, it will cease to exist as soon as any ingenious man shall undertake to examine the subject, for our materials for making brass are as good as any in the world. The quantity of charcoal which is used, is not the same at all works, it is generally about a fourth part of the weight of the calamine; an excess of charcoal can be attended with no other inconvenience than that of uselessly filling up the pots in which the brass is made; but powdered pitcoal, which is used at some works in conjunction with, or in the place of charcoal, greatly injures the malleability of the brass. As to black jack, the other ore of zinc, it is not so commonly used as calamine for the making of brass. The manufacturers have been somewhat capricious in their sentiments concerning it, some have prefered it to calamine, and others have wholly neglected it; and the same persons at different times have made great use of it, or entirely laid it aside. There must have been some uncertainty in the produce or goodness of brass made by this mineral, to have occasioned such different opinions concerning it, and this uncertainty may have proceeded either from the variable qualities of the mineral itself, or from the unskilfulness of the operators in calcining, &c. a mineral to which they had not been much accustomed. Several ship loads of it were sent a few years ago from Cornwall to Bristol, at the price of 40 shillings down to a moidore a ton.* Upon the whole, however, experience has not brought it into reputation at Bristol. [4 *Wats. Ess.* 48—54.

Dr. Aikins' article which is fuller, is as follows.

This very important alloy is a mixture of copper and zinc in various proportions, so intimately united as to form a homogeneous malleable yellow metal, appli-

* Miner. Cornu. p. 47.

cable to a vast variety of purposes and capable of being wrought with the greatest facility.

It is not easy to obtain a perfect union of zinc and copper by mere fusion in open vessels, for at a heat less than is required to melt the copper, the zinc readily takes fire and much of it burns off before it has time to mix with the other metals, so that the proportion of zinc is constantly lessening by volatilization. Even after both metals are fused, the zinc continues to burn off in uncovered vessels, and at last scarcely any thing but copper would be left. In order therefore to combine copper most intimately with zinc, and yet to preserve its malleability, the ingenious process of *cementation* has been resorted to in the manufacture of brass, which is performed by heating in a covered pot alternate layers of copper in small pieces, with zinc ore and charcoal, and continuing the fire till the copper is thoroughly impregnated with the zinc.

Zinc being a volatile metal can only be procured from its ores by sublimation; the process for obtaining it (which will be described more at length under that article) being to heat strongly a mixture of its ore with charcoal in a vessel closed on all sides, except where it admits a tube, the lower end of which dips in water: as soon as the charcoal reduces the oxyd, the metal rises in vapour through the tube and condenses in the water below. A similar reduction takes place in brass-making, only the vapour of the zinc instead of being conveyed out of the crucible in which it is formed, unites with the copper enclosed in the same vessel, and the whole melts down into brass. A less heat is required in brass-making than that which fuses copper, the zinc being able to penetrate the copper when thoroughly red hot, and melting it down as soon as it becomes brass.

Brass is manufactured in many countries, but no where more extensively and better than in England, where

both the materials are in great abundance. The ores of zinc are several species of *calamine* and of *blende*, called by the miners *Black-Jack*, which are found abundantly in Devonshire, Derbyshire, and North-Wales, generally accompanying lead ores. These are chiefly oxyds or carbonated oxyds of zinc, and require a previous calcination before they are fit for brass-making. Blende is a sulphuret.

At Holywell, in Flintshire, the calamine which is received raw from the mines in the neighbourhood, is first pounded in a stamping mill, and then washed and sifted in order to separate the lead, with which it is largely admixed. It is then calcined on a broad shallow brick hearth, over an oven heated to redness, and frequently stirred for some hours. In some places a conical pile is composed of horizontal layers of calamine alternating with layers of charcoal, the whole resting on a layer of wood in large pieces, with sufficient intervals for the draught of air. It is then kindled, and the stack continues to burn till the calamine is thoroughly calcined. The calamine thus prepared is then ground in a mill, and at the same time mixed with about a third or a fourth part of charcoal, and is then ready for the brass-furnace. In some places pit-coal is ground with the calamine instead of charcoal, but this is found to injure the malleability of the brass obtained.

The brass-furnace* has the form of the frustum of a hollow cone, or a cone with the apex cut off horizontally. At the bottom of the furnace is a circular grate or perforated iron plate, coated with clay and horse-dung, to defend it from the action of the fire. The crucibles stand upon the circular plate, forming a circular row with one in the middle. The fuel, which in England is coal, is thrown round the crucibles, being let down through the

* Keir in a note to the article *Brass* in Macquer's Chem. Dict.

upper opening or smaller end of the cone: over this opening is a perforated cover made of fire-bricks and clay, and kept together with bars of iron so as to fit closely. This cover serves to regulate the heat in the following manner: the draught of air is formed through an under-ground vault to the ash-hole, thence through the grate and round the crucibles, and through the smaller upper opening into an area where the workmen stand, which is covered by a large dome and a chimney to convey the smoke into the outer air. When the draught is the strongest, and the heat is required of the greatest intensity, the cover is entirely removed and the flame then draws through the upper opening of the furnace to a considerable height into the outer brick dome; when the heat is to be lessened the cover is put on, which intercepts more or less of the draught from the furnace, as more or fewer of the holes of the cover are left unstopped.

The crucibles are charged with the mixed calamine and charcoal, together with copper clippings and refuse bits of various kinds, and sometimes brass clippings also, most of which are previously melted and run into a small sunk cistern of water through a kind of cullender, which divides the metal into globules, like shot. Powdered charcoal is put over all, and the crucibles are then covered and luted up with a mixture of clay or loam and horse-dung.

The time required for heating the crucibles and compleating the process varies considerably in different works, being determined by custom, by the quantity of materials, the size of the crucibles, and especially the nature of the calamine. In the great way from ten to twenty-four hours are required. At Holywell, in Flintshire, about twenty-four hours are taken.

During the process, and especially towards the latter end, part of the reduced zinc which escapes absorption by

the copper, finds its way in vapour through the luting of the crucible-lids, and burns around them with the beautiful blue flame and dense white smoke peculiar to this metal. Of course, this is so much wasted.

The heat required for brass-making is somewhat less than what would be necessary to melt large masses of copper, brass being the more fusible of the two, and, as it should seem, the vapour of zinc being able to penetrate copper as soon as it is softened by a full red heat. When the brass is judged to be complete, and the saturation of the copper with zinc to be as high as possible, the heat is increased to melt the whole down into one clean mass at the bottom, the crucibles are taken out and the metal poured into moulds. At Holywell, out of the six crucibles used to one furnace, the quantity of brass obtained is about as much as would fill one of them. This makes in subsequent manufacture a single large plate, which is manufactured in the same way as copper plate. Or, more accurately, from forty pounds of copper and sixty pounds of calamine, about sixty pounds of brass are obtained, besides the loss of a good deal of zinc by the unavoidable escape of much of it in form of vapour through the pores of the lute or the crucible-covers.

The above is the usual process of brass-making in this country, and is essentially the same wherever this alloy is manufactured; but with some variation as to the choice of ingredients, their proportions, the time of fusion, the shape of the furnace and other smaller circumstances.

At Goslar, in Saxony, where brass is largely made, the zinc is furnished not by a native calamine, but the *cadmia* or sublimed oxyd of zinc, which is collected for this purpose in a particular part of the chimnies of the reverberatory furnaces in which the Saxon lead ores and blendes are roasted.

A great variety obtains in the respective proportions of

the ingredients. According to Swedenborg* they are, in Goslar, 30 parts of copper, 40 to 45 of cadmia, and twice the volume of charcoal; at Paris, and in many of the French manufactories, they are, 35 of copper, 35 of old brass, 40 of calamine, and 20 to 25 of charcoal; in Sweden, 30 of copper, 20 to 30 of old brass, and 46 of calamine, with charcoal sufficient; or, 40 of copper, 30 of old brass, and 60 of calamine; and in England, generally about 40 of copper and 60 of calamine. The product of brass varies also, but it seems to be in few places so great as in some of the English works, where, as already mentioned, 40 pounds of copper become in the process 60 pounds of brass. This superior quantity is ascribed partly to the goodness of the calamine and partly to the smallness to which the copper is previously reduced by being poured melted into cold water, and thus affording a great surface of metal to the action of the zinc vapour.

At Stolberg,† near Aix-la-Chapelle, where brass is very largely manufactured, the furnaces are cylindrical, and each contains eight crucibles arranged in two tiers of four each. These crucibles are fifteen inches high, twelve inches deep, and eight or nine inches wide. The proportions of ingredients are 40 lbs. of copper, 65 lbs. of calamine, and double its volume of charcoal. After the fire has been kept up for twelve hours, the crucibles are uncovered, and a workman takes off with an iron trowel all the scum and charcoal which swim upon the liquid metal, and which is called *arkest*. When examined with a glass, this is found to consist of calamine and copper particles, cohering together but not completely united. The brass resulting from this first process is coarse, brittle, and unequal in texture, and requires a second fusion before it

* Macquer's Dictionary. † Repertory, vol. xiv.

is fit for use. For this purpose the same crucibles are again employed and are filled, first with three handfuls of the mixture of calamine and charcoal, over which are put two or three pounds of the impure brass broken in pieces, then more calamine and charcoal, with a lump of the *arkest*, and over all, calamine and charcoal powder. The crucible is then strongly heated for two hours, after which the brass is fit to be cast into plates, which is done here in the following manner.

A mould is formed of two blocks of granite, five feet long, three and a half broad, and eight inches thick. They are placed one above the other, the upper one being only moveable, and furnished with a tackle and pullies for that purpose, and before casting, the surface is smeared with cow-dung. To give the plate the requisite thickness, hoops of iron of different dimensions are adapted to the under stone, so as to confine a determinate quantity of melted metal. The stones are then gently inclined and the melted brass let in between them. These plates are afterwards laminated: some of them are cut into slips by strong shears, for the further purpose of being drawn into wire, and otherwise manufactured in various ways.

A single process, where the fire is kept up long enough and the materials are good, is certainly sufficient to make good malleable brass, but it is probable that the excellence and beauty of the article are improved by making it undergo a second cementation with fresh calamine and charcoal.

In the laboratory brass may be made very well in the small way in a much shorter time. Put into a crucible a mixture of calamine and charcoal, bury it in the requisite proportion of copper shot, cover the whole with charcoal powder, lute on a cover to the crucible, and heat slowly in a wind-furnace for half an hour, till the zinc begins to burn off in a blue flame round the top of the crucible,

then raise the fire and heat briskly for half an hour longer.

This process of cementation is also neatly shewn by the following management, as given by Cramer. Put the mixture of calamine and charcoal into a crucible, cover it with a thin layer of clay, over which when dry lay a thin plate of copper, cover the whole with fine charcoal powder, and lute on a cover to the crucible. Apply heat gradually, and the vapour of the reduced zinc will rise through the floor of clay, penetrate the red-hot copper plate above it, and gradually convert it into brass, which at the end of the operation will be found lying melted on the stratum of clay. The increase of weight gained by the copper in this operation will afford a good practical test of the goodness of the calamine, and its fitness for brass-making in the great way.

The most important properties of brass compared with copper are the following: the colour of brass is much brighter, and more approaching to that of gold; it is more fusible than copper; less subject to rust and to be acted on by the vast variety of substances which corrode copper with so much ease; and it is equally malleable when cold, and more extensible than either copper or iron, and hence is well fitted for fine wire. Brass however is only malleable when cold. Hammering is found to give a magnetic property to brass, perhaps however only arising from the minute particles of iron beaten off the hammer during the process and forced into the surface of the brass, but this circumstance makes it necessary to employ unhammered brass for compass-boxes and similar apparatus.*

The expansion of brass has been very accurately determined, as this metal is most commonly used for mathematical and astronomical instruments, where the ut-

* The brass contains iron. T. C.

most precision is required. Mr. Smeaton found that 12 inches in length of cast brass, at 32°, expanded by 180 degrees of heat (or the interval from freezing to boiling water) 225 ten thousandth parts of an inch. Brass wire under the same circumstances expanded 232 parts; an alloy of 16 of brass with 1 of tin expanded 229 parts. The expansion of hammered copper is only 204 such parts, but that of zinc is 253, so that brass holds a middle place, in this respect, between its two component metals.

Most of the zinc readily burns off from brass when kept melted in a strong heat with free access of air. When the heat is equal to that of melted copper, the zinc takes fire and slowly burns away. At last little else but copper remains, but still united with a small portion of zinc, which no further continuance of the fire will entirely separate.

Some kinds of very fine brass are said not be made by cementation in the way already described, but by a more speedy and direct union of copper and zinc, care being taken to prevent the access of air to the materials while in fusion. Very fine brass may also be made by mixing together the oxyds of copper and zinc, and reducing them with a carbonaceous flux. This idea is ingenious, and from the intimate mixture of the two metals which it promises, it deserves to be further pursued. M. Sage, gives the following experiment to this purpose. Mix together 50 grains of the oxyd of copper, remaining after the distillation of verdigris (which is very pure) with 100 grains of lapis calminaris, 400 grains of black flux, and 30 grains of charcoal powder; melt the mixture in a crucible till the blue flame is seen no longer round the lid of the crucible, and when cold a fine button of brass is found beneath the scoria, weighing a sixth more than the copper alone, obtainable from its oxyd in the same way but without the calamine. This brass has a very fine colour like gold.

On this experiment M. Sage observes that there appears to be a point of mutual saturation between the two metals, which is when the copper retains one-sixth of zinc, and this portion it will retain however long it is heated, provided the surface of the melted metal be covered to protect the zinc from the action of the air; but if the brass contains a greater proportion of zinc, precisely this excess will escape, even in covered vessels, and will burn when it comes out to the air. The same chemist also observes that the colour is the finest at the above proportion. These experiments seem to require further confirmation; but at present we may reckon that to be the most perfect brass which is composed o about 14.28 per cent. of zinc and 85.7 of copper, and which is not liable to any alteration in its constituent parts by successive or long continued fusions, provided the access of air be prevented.

The *analysis* of brass has been attempted in various ways, and several processes have been given of different merit.

Brass may be to a certain degree analysed by simply being kept in fusion at a high heat with free access of air. The zinc readily burns, and by far the greater part of it escapes, and when the blue flame of the metal ceases the analysis is supposed to be complete, the loss of weight on the remaining metal indicating the quantity of zinc. But this is inaccurate from two causes; first, that a portion of zinc always remains in the copper however long the heat be continued, and secondly that part of the copper oxydates in the process, and thereby gains an increase of weight. Both these circumstances therefore contribute to indicate a smaller proportion of zinc than is really the case.

A simple solution of brass in the sulphuric acid and subsequent crystallization has also been recommended, on the idea that the crystals of sulphat of zinc could readi-

ly be obtained separate from those of the sulphat of copper. But though this separation takes place to a considerable degree it is not complete, for at the last the crystals of each salt are somewhat alloyed with the other, and the trouble of picking out the crystals when very small is extreme.

M. Dize* proposes the following methods. 1. Dissolve the brass in nitric acid, which takes up the copper and zinc and leaves any tin with which it is often alloyed. Decompose the clear nitrated solution by potash, redissolve the precipitate in sulphuric acid, and add a piece of clean bright iron to the solution, previously diluted with six times as much water. The copper is by this means precipitated in a metallic state, and the solution now holds sulphat of iron and sulphat of zinc. Add gallic acid, which will slowly separate the iron and leave the zinc. Lastly, decompose the sulphat of zinc by a carbonated alkali, and estimate the quantity of zinc contained in the carbonated oxyd of zinc thus obtained, by proportions which will be presently mentioned. The above method is useful, but the separation of the iron by the acid of galls is excessively tedious.

2. Dissolve the brass in nitric acid. Dilute with six parts of water, and immerse in the solution a cylinder of bright clean lead. The copper speedily separates in the metallic form round the lead, which last takes its place in the solution. As this process advances, the liquor loses its blue colour, and when all the copper is separated it is slightly yellow. To be certain that no copper remains in the solution, add a fresh clean piece of lead and boil for some time. The liquor now contains nitrat of lead and nitrat of zinc. Sulphuric acid will now precipitate the

lead in the form of an insoluble sulphat, and the nitrated zinc may then be decomposed by a carbonated alkali.

On this precipitation however there are several things to be observed. Copper, as Vauquelin remarks,* when dissolving in nitric acid absorbs nearly $\frac{40}{100}$ of its weight of oxygen, but lead under the same circumstance absorbs only $\frac{16}{100}$. Hence one hundred parts of copper dissolved in nitric acid would require for their disoxygenation (a process which takes place whenever a metallic oxyd in solution is precipitated by the immersion of another metal in its metallic state) full 250 parts of lead, which last is of course oxydated in proportion as the copper is precipitated in the metallic form. But this large quantity of oxyd of lead cannot be held in solution by the nitric acid, except this is largely in excess, and this explains the reason of the appearance of a portion of oxyd of lead (as M. Dize has observed) which forms at the latter end of the process and mixes with the newly precipitated metallic copper, so as to require a subsequent operation to separate them. Nor will an excess of nitric acid ensure the purity of the precipitated copper, for it happens here, as is now found to take place in very many of the reguline metallic precipitates, that the newly-separated metal is not pure, but largely alloyed with the metal added as a precipitant. Therefore the loose flocculent metal which forms around the piece of lead is not pure copper, though it has a perfect cupreous appearance, but is copper largely alloyed with lead. Vauquelin found that if 50 grains of pure copper are dissolved in an excess of nitric acid, and then entirely precipitated by metallic lead, of which about 220 grains are required, the cupreous precipitate now weighs 138 grains instead of the original 50, and therefore is not pure copper but an alloy of 50 parts of copper with

* An. Chim. tom. 28.

88 parts of lead. This method therefore of analysing brass cannot be depended on, unless the cupreous precipitate be afterwards separately treated to separate the lead, which would render the analysis very complicated.

The following methods are given by Vauquelin.

3. Dissolve a known weight of brass in nitric acid; put it into a well closed bottle and add caustic potash to excess, so that there shall be a very sensible alkaline taste in the liquor, shake the mixture well, and keep it some time in digestion. By this process the oxyds of copper and zinc are first both precipitated by the alkali, and afterwards the zinc alone redissolved in the excess of potash, so that the clear solution is oxyd of zinc in potash, and the sediment left undissolved is the oxyd of copper. This oxyd is brown and nearly of the colour of metallic copper, but when thoroughly washed and gently dried, it only contains 65 per cent. of the metal. If a previous assay has shewn that the specimen of brass contained only copper and zinc, when the weight of the former is known, that of the other may readily be inferred; or else, the alkaline solution of zinc may be supersaturated with sulphuric acid, so as first to precipitate and afterwards to redissolve the metal, when the sulphuric solution may be decomposed by a carbonated alkali. A very trifling quantity of copper passes into the alkaline solution of zinc, occasioned by the action of a small quantity of ammonia, generated by the nitrated metals when caustic alkali is added to them. If necessary this might be again separated by a heat cautiously kept below boiling, which would expel the ammonia, the cause of this error, but if brought fully to boil some of the zinc would separate from the alkali and cause a much greater error than before.

4. Dissolve brass in sulphuric acid, dilute with twenty times as much water, and immerse a stick of zinc exact-

ly weighed. The copper soon completely precipitates in the metallic form, and requires only to be well washed and weighed. The solution now contains only the zinc of the brass, together with the zinc lost from the piece immersed to precipitate the copper. By weighing the remainder of the stick of zinc, and precipitating the whole by carbonated potash or soda, an easy calculation will determine how much of the oxyd of zinc is derived from the zinc contained at first in the brass. Or, more simply, this may be inferred from the copper obtained, and the quantity of brass originally employed.

It remains on the subject of analysis to give the constituent parts of carbonat of zinc. M. Dize dissolved 100 parts of zinc in nitric acid, precipitated it by carbonated soda, and this product well washed and *dried* now weighed 180 parts. Hence 100 parts of carbonat of zinc thus prepared would indicate 55.5 of metallic zinc.

On the other hand Vauquelin found that carbonat of zinc obtained from the sulphat by carbonated potash, well washed, and calcined in a crucible to expel all the carbonic acid, contained 69 per cent. of metallic zinc. Hence the carbonat obtained by Dize must have been dried at a low temperature, probably that of boiling water, and from either of the above data the proportion of zinc may be estimated; or else the carbonated oxyd may be mixed with about a fourth of charcoal and strongly heated in an earthen retort with the beak dipping in water, by which the zinc will be reduced and will rise into the neck of the retort, or partly fall into the water beyond.

Analysis shews a vast variety in the proportions of the different species of brass used in commerce. In general the extremes of the highest and lowest proportions of zinc are from 12 to 25 per cent. of the brass. Even with so much as 25 per cent. of zinc, brass, if well manufactured,

is perfectly malleable, though zinc itself scarcely yields to the hammer. M. Dize analized a specimen of remarkably fine brass made at Geneva, for the purpose of escapement wheels and the nicer parts of watch-making, the perfect bars of which bear a very high price. This metal unites great beauty of colour to a very superior degree of ductility. It was found to consist of 75 of copper with 25 of zinc, and probably too the copper was Swedish or some of the finer sorts. The common brass of Paris seems to contain about 13 per cent. of zinc, the English probably more.

The uses of brass are too numerous to be mentioned. It is applicable to an infinite variety of purposes, is easily wrought by casting and hammering, and by the lathe, its wire is eminently useful, and it takes a high and very beautiful polish. The appearance of brass is given to other metals by washing them with a yellow lacquer or VARNISH, a substitution often very much to the detriment of the manufactured article. 1 *Aikin*, 166.

In 1781 a patent was granted to Mr. James Emerson for his invention of making brass of copper and zinc, (spiauter, spelter as the Germans call this semi-metal).

The patentee directs the spelter to be melted in an iron boiler, then passed through a perforated ladle, and placed over a vessel containing water, by which means the zinc will be granulated. Fifty-four pounds of granulated copper, (copper shot) are now mixed with ten pounds of calamine calcined and pulverized, and about one bushel of charcoal. One handful of this mixture is then put into a casting pot, and then three pounds of the granulated zinc, upon which the composition before specified is laid till the vessel is filled. Eight similar pots are to be supplied with the same materials, and the whole must be submitted to the heat of a furnace for 12 hours, when the process will be completed, and 82 lbs. of brass will be

procured, which he says will be of a very superior quality to that procured from copper and calamine alone.

This process like most other patent specifications, requires explanation.

1. It is evident that the pots must be furnished with covers otherwise the zinc will sublime and be wasted.

2. The degree of heat is not mentioned, whether the copper should be quickly melted or not, which in the common process for making brass does not take place till the latter end of the process.

3. Much must depend on the analysis of the calamine. Some calamine contains lead, all contain iron. Calamine varies in its contents of zinc from 45 to 65 per cent. According to Watson, calamine from Poland yielded out of 16 parts 2 parts and an half: from Breslaw 4 parts and an half: from Hungary 2 parts and one-third: English calamine three parts: another specimen from Holywell in Flintshire 7 parts.

I copy the following from 2 Jamison's Mineralogy 413. Calamine English.

	From Holywell.	Derbyshire.	Somersetshire.	Wantock head.
Ox. of zinc	65	65.2	64.8	66
Ox. of iron	1			33
Carb. acid	28	34.8	35.2	
Water	6			
	100	100	100	100

German Calamines from Fribourgh 36 oxyd of zinc, 52 silica, 12 water: from Bleyberg 71.4 oxyd zinc, 13.5 carbonic acid, 15.1 water.

Hence according to the analysis of Jamison in this process of Emerson's, ten pounds of calamine may be supposed to yield six pounds and a third of zinc, which with three of granulated zinc for each pot will make thirty pounds and one-third of zinc to fifty-four of copper: if the produce be 82 lbs. then two pounds and one-third

will be dissipated. This is a very large proportion of zinc, and would form what is called Prince Rupert's metal.

The following observations of Bishop Watson, are worth attention.

The calamine of *Bohemia* contains iron: most of our English calamine contains lead; and there are some sorts which contain both iron and lead, and other metals in different proportions: these sorts can seldom be freed from the extraneous metals, and hence, in the ordinary method of making brass, they will be mixed with it, being fusible in the degree of heat usually employed in making brass. *Cramer* mentions a very ingenious method of making brass, by which, if it should be thought necessary to do it, the brass may be preserved pure from these heterogeneous mixtures. He orders the calamine and charcoal to be mixed with moistened clay, and rammed to the bottom of the melting pot, and the copper mixed with charcoal to be placed upon the clay; then, the proper degree of heat being applied, the vapour of the zinc contained in the calamine will ascend through the clay, and attach itself to the copper, but the iron, or lead contained in the calamine, not being volatile, will remain in the clay, and the brass when the whole is melted will not be mixed with them, but rest pure on the surface of the clay. Mr. *John Champion*, brother to him who first established the manufactory of zinc at Bristol, is a very ingenious metallurgist, and he has lately obtained a patent for making brass by combining zinc in vapour with heated copper plates, and the brass is said to be very fine; whether the process he uses has any correspondence with this mentioned by Cramer, or not, his brass will certainly be free from the mixture of lead, &c. But the care to purify brass from such metallic mixtures as may be accidentally contained in the calamine, is, or is not necessary, according to the purposes

to which brass is applied. These mixtures may probably injure the malleability of the brass, but they may at the same time increase its hardness, or render it susceptible of a better polish, or give it a particularity of colour, or some other quality by which it may be more useful in certain manufactories, than if it was quite free from them, and consisted of nothing but of the purest metallic part of the calamine, united to the purest copper. This may be illustrated from what is observable in other metals. The red iron ore from *Furness* in *Lancashire* produces an iron, which is as tough as *Spanish* iron, it makes very fine wire; but when converted into bars, it is not esteemed so good as that which is made in the forest of *Dean*, and other places. There are but few sorts of iron which, though useful in other respects, are fit for being converted into steel: some sorts of iron will admit an high polish, as may be seen in many expensive grates which are sold as grates of polished steel, though they are nothing but iron, whilst others take but a very indifferent polish; the *Swedish*, *Russian*, and *English* irons, and even the irons made at different furnaces in the same country are respectively fit for some purposes, and unfit for other; he who should attempt to use the same iron for the making of wire, and for coach and waggon wheels, would betray great ignorance in his business. In like manner, a notable difference may be observed in different sorts of copper, yet all of them have their respective uses: the Swedish copper is more malleable than the copper of Hungary; the copper of Anglesea differs from the copper of Cornwall and of Staffordshire. The braziers prefer that copper which they can work with the greatest facility, but the malleability of copper should not be esteemed the only criterion of its goodness; for the copper which is less malleable may admit a finer polish, and may last longer when exposed, as in breweries, in the navy, &c. to the action of the fire, than the copper which

is more malleable. This has been proved by experiment. Three plates of copper, equal to each other in surface and thickness, were exposed, for the same length of time, to a violent fire, with a view of seeing which would best sustain its action; one plate was made of copper which had been purified by a chemical process, another was made of copper from Hungary, and the third of Swedish copper. The purified copper, when freed from the calcined scales, had lost 5 grains of its weight, that of Hungary had lost eight, and that of Sweden eleven grains.

[4 *Watson* 63—69.

This last experiment can be accounted for, inasmuch as copper is less oxydable than iron or lead or antimony, and therefore the purer it is the less apt it will be to scale off. T. C.

Prince's Metal (Prince Rupert). This metal was prepared by Admiral Prince Rupert, in 1682. Three parts copper being melted and covered with charcoal, one part of zinc is added, and the vessel covered close. Or 8 parts brass being melted, one part of zinc is added with charcoal, and the vessel covered.

Pinchbeck.—This is a redder metal, made by fusing one part of brass with one and a half or two parts of copper.

Tombac.—Three and a half of copper to one and a half of brass.

Or de Manheim. Similor.—Marggraf melted pure zinc and pure copper together, in a great variety of proportions, and he found that eleven, or even twelve parts of copper being mixed with one part of zinc, (by putting the zinc into the copper when melted) gave a most beautiful and very malleable tombac or pinchbeck. Mr. Baumè gives the following process for making a metal, which he says is called *Or de Manheim*, and which is used for imitating gold in a variety of toys, and also on lace.—Melt an ounce

and an half of copper, add to it three drams of zinc, cover instantly the mixture with charcoal dust to prevent the calcination of the zinc; this covering of the melted mass with charcoal is certainly serviceable in the way the author mentions; and it is on a similar principle, that when they melt steel at Sheffield they keep the surface of it covered with charcoal; but I think it probable also, that the charcoal contributes to exalt the golden colour of the pinchbeck. These yellow metals are seldom so malleable as brass, on account of the zinc which is used in making them not being in so pure a state, as that is which is combined with copper when brass is made; yet it appears from the experiments of Marggraf and Baumè before mentioned, that when pure zinc and pure copper are used in proper proportions, very malleable brass may be made thereby. Mr. Emerson has a patent for making brass with zinc and copper, as I have been informed, and his brass is said to be more malleable, more beautiful, and of a colour more resembling gold than ordinary brass is. It is quite free from knots or hard places, arising from iron, to which other brass is subject, and this quality, as it respects the magnetic needle, renders it of great importance in making compasses. [4 *Watson* 45—48.

The last observation of Bishop Watson agrees with the experiments of M. Cavallo, who found almost all the specimens of brass he tried, to be magnetic. The great inconvenience of this property, when the case of the compass is brass, is obvious. T. C.

Mesure's Metal. Substitute for Gold.—Mr. Mesure of Craven-buildings, Drury-lane, having been, in consequence of the great scarcity and exorbitant price of gold, induced to turn his attention to the discovery of a substitute for that metal, has at length announced the complete success of his exertions. The metal which is the result

of them approaching nearer to the qualities of gold, except in weight, than any other yet discovered. It takes a most beautiful polish, is less liable to tarnish or to be scratched than gold, and though very ductile, it is capable of being rendered extremely strong and elastic: It is peculiarly adapted for watch cases, snuff boxes, and all the variety of trinkets for which gold is at present employed: the inventor supplies the unwrought metal at a very reasonable rate.—4 *Com. Mag.* 362.

A summary of these alloys of copper and zinc, and copper and tin, is given by Aiken as follows:

Copper with Zinc. Copper nearly saturated with zinc, that is, in which the latter makes about a fourth (more or less) of the mixture, forms *brass*, the most important of all the alloys of this metal, and which has been fully described under that article. With a much less proportion of zinc the colour of the alloy approaches very nearly to that of gold, and the malleability increases. Mixtures chiefly of these two metals are used to form a variety of yellow or gold-coloured alloys, known by the names of *Tombac, Manheim or Dutch Gold, Tinsel, Similor, Prince Rupert's Metal, Pinchbeck*, &c. but the precise composition varies according to the fancy or the experience of different manufacturers. The Dutch gold may be beaten out into extremely fine leaves, which, when fresh, have nearly the brilliance of gold-leaf, and are used as a cheap imitation of it, but they tarnish very soon. The mixture may be made either by directly melting copper and zinc, or by mixing brass and copper. In either case the copper should be melted first, and the zinc added afterwards, the whole stirred together with wood, covering it with a little charcoal, and poured out immediately, to prevent the loss by the burning off of the zinc.

Several direct experiments on the union of copper and zinc in different proportions were made by Marggraf.

In all, the copper was the purest Japanese, and the mixture was made in the way above mentioned. With 8 drams of copper and as much zinc, much of the latter unavoidably burnt off and the alloy only weighed 12 instead of 16 drams, the mixture was hard, brittle, yellow, and of a radiated texture. With 16 drams of copper and 8 of zinc, the loss by burning was only one sixth of a dram. The alloy was softer than the last, still radiated, yellow, and began to be a little malleable. From this, successively diminishing the proportions of zinc, the alloy became softer, more malleable, and of a colour more and more approaching to gold: and at last, with 11 or 12 of copper and 1 of zinc, the finest golden tombac was produced. According to Wiegleb the Manheim gold is made by melting separately 3 parts of copper and 1 of zinc, mixing them, covering with charcoal, stirring with a stick and cooling immediately. These proportions scarcely differ from those of some kinds of brass. Beaumè gives for the same metal 4 of copper and 1 of zinc, whence it is obvious that the proportions are quite arbitrary, but it appears that the alloy is not made, as brass is by cementation, but by simple mixture of the metals. A very small quantity of tin is sometimes employed, but this metal has the disadvantage of remarkably diminishing the malleability of copper and its alloys. A fine malleable tombac is made, however, with 16 of copper, 1 of zinc, and 1 of tin. An alloy of 12 of brass and 1 of tin is scarcely malleable.

A kind of tombac is the material of which a large proportion of the Roman coins was composed. Klaproth on analyzing several, struck during the first century of the emperors, found them all to consist either of pure copper, or of copper and zinc, in which the latter metal made generally from a fifth to a sixth of the mass. A little tin

and lead were found in some, but in such small proportion as to appear only an accidental impurity.

Copper with Tin.—The alloys of copper and tin are extremely important in the arts, and curious as chemical mixtures. They form in different proportions mixtures which have a distinct and appropriate use. Tin added to copper makes it more fusible, much less liable to rust or corrosion by common substances, harder, denser, and more sonorous. In these respects the alloy has a real advantage over unmixed copper, but this is in many cases more than counterbalanced by the extreme brittleness, which even a moderate portion of tin imparts, and which is a singular circumstance considering how very malleable both metals are before mixture, and the remarkable softness and ductility of tin.

The sensible qualities of the different mixtures are the following. Copper alloyed with from 1 to about 5 per cent. of tin is much harder than before, the colour yellow with a cast of red, and the fracture granular. It is still considerably malleable. This appears to be the usual composition of many of the very ancient copper tools and weapons before the common use of iron; whence it appears that the ancients did not (as has often been supposed) possess any peculiar art of hardening pure copper, otherwise than by mixture. It is certain that the quenching of red hot copper in water will not at all make it harder, or have any such effect as it has upon iron. An alloy in which the tin is from one-tenth to one-eighth of the whole is hard, brittle, but still a little malleable, close-grained, and yellowish-white. Where the tin is as much as one-sixth of the mass, it is now entirely brittle, and continues so in every higher proportion. The yellowness is not entirely lost till the tin is above 7-23ds of the whole.

Copper, or sometimes copper with a little zinc, alloyed with as much tin as will make from about one-tenth to

about one-fifth of the whole, forms an alloy which is the principal, and often the only composition for bells, brass cannon (so called) bronze statues, and several smaller purposes, and hence it is called *Bronze*, or *Bell-Metal* (always observing that there is no perfect uniformity in the different alloys under these names, either in the proportion or the actual number of ingredients) and it is excellently fitted for these purposes, by its hardness, density, sonorousness, and fusibility, whereby the minute parts of hollow moulds may be readily filled before it fixes in cooling. For cannon, a lower portion of tin seems to be used. According to Dr. Watson, the metal used at Woolwich is 100 parts of copper and 8 to 12 of tin. Hence it still retains some little malleability, and of course is tougher than with more tin. Bronze cannon are much less liable to rust than those of iron, but in large pieces of ordnance, by very rapid firing the touch-hole is apt to melt down and spoil the piece; of which there is a remarkable instance at the Tower of London of a mortar of the largest calibre thus spoilt at the siege of Namur. On account of the sonorousness of bronze, these cannon give a much sharper report than those of iron, which for a time impairs the hearing of the people that work them. A common alloy for bell-metal is about 80 of copper to 20 of tin; or where copper, brass, and tin are used, the copper is from 70 to 80 per cent. including the portion contained in the brass, and the remainder is tin and zinc. The zinc certainly makes it more sonorous. Antimony is also often found in small quantity in bell-metal. Some of the finer kinds used for small articles contain also a little silver, which much improves the sound.

When the tin is nearly one-third of the alloy it is then most beautifully white, with a lustre almost like that of mercury, extremely hard, very close-grained, and perfectly brittle. In this state it takes a most beautiful polish,

and is admirably fitted for the reflection of light for all optical purposes. It is then called *speculum metal*, which however, for the extreme perfection required in modern astronomical instruments, is better mixed with a very small proportion of other metals particularly arsenic, brass, and silver. But the basis of these compositions is copper alloyed with nearly half its weight of tin. The use of this alloy for the same purpose is of great antiquity, and certainly was in frequent use in the time of Pliny. Klaproth analyzed a portion of an ancient speculum in the following manner. The fragment was compact, very hard, and brittle, the fresh fracture greyish white, which by polishing acquired a beautiful lustre. A hundred grains were heated with nitric acid, whereby a blue solution was made, and a part remained undissolved. The solution being first tried without effect with muriat of soda for silver, was mixed with a solution of sulphat of soda, which gave a white precipitate of sulphat of lead, equivalent to six grains of lead. The copper was then separated by iron, and amounted to 62 grains. The undissolved portion slowly digested with muriatic acid, gave a straw-yellow solution, which, decomposed by zinc, gave 32 grains of metallic tin. This speculum therefore consisted of 62 parts of copper, 32 of tin and 8 of lead, which last was probably an adulteration of the tin and not added designedly.

When more tin is added than amounts to half the weight of the copper, the alloy begins to lose that splendid whiteness for which it is so valuable as a mirror, and becomes more of a blue-grey. As the tin increases, the texture becomes rough-grained, and, as it were, rotten, and totally unfit for manufacture. The speculum metal is therefore in the highest proportion of alloy of tin that copper will admit for any useful purpose.

A perfect speculum-metal should be quite white with-

out shewing any cast of yellow when polished, not very liable to tarnish, quite free from pores even when examined by a lens, of a certain coherence or toughness to bear the grinder, and for the convenience of working, as soft as may be consistent with the other requisites.

Mr. Mudge, whose specula were celebrated for their goodness, observes, that the extreme of whiteness is given by 32 parts of copper and 16 of tin, but this is excessively hard and brittle; that 32 of copper with 14 1-2 of tin is still quite white and as hard as can be wrought. He also observed by many trials, that the metal to turn out free from pores should be twice fused, that is, the first time for the purpose of mixture (in which the copper is to be first melted separately) and then remelted with as little heat as possible, for casting. As there is always some loss by the calcination, chiefly of the tin, a little allowance in the proportion of this latter may be made on account of the double fusion.

The most elaborate mixture and accurate directions on this important subject are given by Mr. Edwards, whose specula are of extreme excellence, and are published in the nautical almanac for 1787, of which the following are the leading particulars.

The quality of the copper should first be tried by adding successively from so much short of half its weight of tin that it proves a little yellow, to the full half of tin, and by comparison ascertaining the maximum of whiteness, observing that beyond this point the alloy begins to lose part of the brilliance of fracture and to become bluish. When this is found, take 32 parts of the copper, melt it, add one part of brass and as much silver, with a little black flux* to cover the surface; when these are melted, stir with a wooden rod, and pour in from 15 to 16 parts of tin (according as found necessary by previous experiment) fused in a separate crucible with a low heat, stir the

* Crude Tartar deflagrated with nitre. T. C.

mixture again, and immediately pour it into cold water. Then in the second melting (with as little heat as will suffice) take for every 16 parts of the composition 1 part of white arsenic, wrap it in paper, thrust it to the bottom of the fluid metal, and stir with a wooden rod till no more arsenical fumes escape, immediately after which cast the metal in a sand-mould. Then while it is still red-hot lay it in a pot full of very hot embers and cool it very slowly: unless this precaution is particularly observed, the metal will fly in pieces when cold, sometimes even long after all such danger is thought to be past; or it will split in the polishing. For the particular manner of constructing the mould, and the whole of the nice and laborious operations of grinding and polishing to a perfectly true figure, the reader is referred to the two papers above mentioned.*

Both the brass, and the silver, and the arsenic appear to have their distinct use. The brass makes the mixture tougher and not so excessively hard and brittle. The silver improves both the texture and colour, but is not an essential though really an useful addition. The arsenic is found by actual comparison to make the metal finer, and particularly closer in texture, and therefore less liable to be porous. It sensibly increases the specific gravity, which, before the arsenic is added, is 8.78, but afterwards, 8.89. It is added in the second melting, that as little as possible may be dissipated in vapour. A greater proportion would make the metal liable to tarnish. An alloy containing 6 of copper, 2 of tin, and 1 of arsenic, is nearly the proportion of Sir I. Newton's specula, which is very good, but polishes somewhat yellow.

The separation of copper from bell-metal and all the tin alloys in the large way, happened to be an object of considerable importance in France in the midst of the revolutionary war, when the importation of copper was nearly impracticable, and a large quantity of it was required for

* And to a paper in part extracted a few pages hence. T. C.

general purposes, and particularly for the coinage. A number of very ingenious experiments were then made on the best method of freeing the metal of church bells from their tin and other alloy, and obtaining thence a good malleable copper with the least possible expence or loss.

The circumstances in which it is worth while to melt down great bells for the sake of the pure copper do not often occur, but the various processes may be here shortly noticed as important to the history of the chemical properties of copper alloys, and as a very happy example of the application of theoretic chemistry to the purposes of manufacture. Pelletier and Fourcroy seem to have chiefly distinguished themselves in this research, and each chemist appears to have followed nearly the same track, but with an acknowledged priority in the former.

The great principle on which all the modes of purifying bell-metal depend, is the much more ready oxydability of tin by the united action of heat and oxygen, than copper. Hence even when bell-metal is simply kept melted in an open vessel, a degree of separation of the two metals begins instantly, the tin oxydating much faster and sooner than the copper, and of course the proportion of copper being therefore constantly increasing in the fluid metal below.

Another equally important circumstance also depending on the much stronger affinity of tin for oxygen, is, that when oxyd of copper is mixed with tin at its lowest state of oxygenation, the tin still retains its superior affinity for oxygen, and deprives the oxyd of copper of this principle, and the products are, tin highly oxygenated and in a pasty semi-fluid mass, and copper in the reguline state, partly collected at the bottom of the vessel and partly in small globules entangled in the oxyd of tin.

The direct experiments of Fourcroy on this point are valuable.

A bell-metal was first made with 80 parts of copper and 20 of tin, both pure.

Of this alloy 100 parts were put on a muffle and exposed for a certain time to a red heat, with access of air. The whole was converted to a grey oxyd and weighed 104 parts. It was then heated strongly for half an hour, and yielded a button of pure copper weighing 54 parts. Consequently 26 parts of copper remained unreduced and mixed with the scoriæ of the oxyd of tin.

A hundred parts were calcined as above till they increased to 117. This being strongly heated for half an hour gave a brown mass, from which no copper separated except a few interspersed globules. This therefore was too much oxygenated, that is, the tin had combined with so much oxygen in the first operation that it could not afterwards separate any from the oxyd of copper.

A hundred parts were treated in the same way till they increased to 112. This melted into a brown mass containing more globules of copper than the last, but still the greater part remained unreduced.

Hence it appears that even an increase of 12 on 100 is too much, and by other experiments, the above chemist fixes the proper point of oxydation at which oxyd of copper is reducible by oxyd of tin to be from 5 to 7 on 100 of common bell-metal. However, when too highly oxygenated metal is mixed with the requisite proportion of fresh metal, the former serves as a reducing flux to the latter, and the whole may then be made to yield a large portion of purified copper. This very ingenious plan has been found to answer extremely well in experiments made in the large way, as will presently be mentioned.

Several substances have been tried that might assist in the first oxygenation of the bell-metal and shorten the process. Of these, nitre and oxyd of manganese answer the most completely. For experiment in the small way, 100

parts of bell-metal were powdered and mixed with about 14 of nitre, and heated, at first slowly, afterwards strongly, and gave from 57 to 63 parts of copper, very malleable, but not quite pure. With a larger quantity of nitre the copper is purer, but more is lost in the scoriæ.

A hundred parts of bell-metal mixed with 25 parts of oxyd of manganese, covered with broken glass, and strongly heated for an hour, gave 36 parts of very good copper. It is of some importance to add glass or some other saline flux, as this brings the whole into thorough fusion, and allows the copper to subside through the vitrified oxyd of manganese. Where this is not done (and in the large way it would add to the expense) much of the copper is entangled in the vitrified manganese, and a subsequent operation is required to separate it.*

In the processes of two other chemists, salt and sand have each been found useful additions in the refining of bell-metal.

We may add the detail of two trials made in the large way by Pelletier and Darcet by order of the French government, the one in which a portion was first oxydated, and this used as a reducing flux for the remainder, without any foreign addition whatsoever: and the other in which the refining was assisted by oxyd of manganese. It may be premised that the manipulation of large quantities is not the same as with small, particularly in the case of reduction to gross powder, which may be easily done in an iron mortar on a few ounces or pounds, but not with any economy on large weights. Large masses therefore are first heated red-hot, when they may be easily broken up and spread about by an iron bar, and this is the way constantly practised.

The first process was that of refining without addition. For this purpose 400 pounds of metal were put on a furnace, and when red-hot broken up with an iron bar, and

* All this strongly bears upon the refining of Copper.

spread about with constant stirring till the whole was converted into a reddish oxyd, somewhat cohering, and shewing the appearance of copper approaching to reduction. The 400 pounds were increased hereby to 425 pounds 2 ounces, making an increase of above six and one-fourth on 100.

Next, 800 lbs. of fresh metal were melted on a reverberatory, and the 425 lbs. 2 ounces of oxyd were added to it with constant stirring for about twenty minutes. The fire was continued for nine hours with occasional stirring of the metal, and samples were drawn from time to time, which shewed a gradual approach in the melted metal to the state of pure copper. As the refining took place at the surface of the fluid metal, or the point of contact between it and the scoriæ, the metal was there purer than at the bottom. Nine hours after the melting of the metal the copper beneath the scoriæ was fine, red, and fibrous, and was then run off into moulds. The scoriæ remained in, for half an hour longer to melt out part of the metal entangled in it, which was then let out, and lastly, the scoriæ itself was raked out, which was a black and pasty mass, that hardened excessively when cold, and still contained some copper entangled in its substance. The results of this operation were 761 lbs. 12 ozs. of copper run into the moulds; 46 lbs. of copper sweated out of the scoriæ, and 7 lbs. 4 ounces of small-grained copper, samples, &c. or in total 915 lbs. of copper from 1200 of metal, or nearly 68 from 100. The scoriæ weighed 474 lbs. and when thoroughly bruised in a stamping mill, and washed, it gave 18 lbs. more of copper.

Thus then by this simple process nearly 70 parts (in all) of very good copper may be got from 100 parts of metal, whose known contents of copper are about 80 per cent.

The second process was that with the assistance of black oxyd of manganese.

In the same furnace 800 lbs. of bell-metal were first melted, and kept very hot, after which 25 lbs. of oxyd of manganese were thrown in, and the whole stirred and mixed with great care. Two hours after, 15 lbs. more of the manganese were stirred in, and the metal even then was sensibly purer than at first. This alternate addition of manganese, and stirring, continued till 100 lbs. of manganese were used, during which the metal constantly kept refining. Ten hours after the first melting, the copper was found to be soft, fibrous, and good, and was run off into moulds. It weighed 520 lbs. The scoriæ was softer than the former, and not so well melted. It weighed 344 lbs. and was still visibly rich in copper, as was proved by after washing. The copper, exclusive of that in the scoriæ, here amounted to about 60 from 100 of bell-metal.

From these and many other experiments it appears that by very simple means from six to seven-eighths of the copper actually contained in bell-metal may be extracted; and in particular circumstances this may be practised to advantage, but on the other hand the tin is lost to most economical uses, as its reduction from the state of an impure semi-vitrified scoriæ is extremely difficult and expensive. [1 *Aikin*, 347.

Copper with Iron.

These only unite when the iron is in small quantity. The alloy is grey, hard, and somewhat brittle.

Tutenag is a white alloy of copper, zinc, and iron, according to Keir, which is very hard, tough, and sufficiently ductile to be wrought into various articles of furniture, such as candlesticks, &c. which take a high polish, and when made of the better sort of tutenag, are hardly distin-

guishable from silver. The inferior kinds are still white, but with a brassy yellow.

The Chinese *Petong* is another fine, white, malleable alloy of copper, the composition of which is not exactly known, but it contains a small portion of silver. Neither of the above metals are imitable by the common processes.

According to Dize, when the iron forms only $\frac{1}{76}$ of the mass it is still magnetical, but not so when it is only about $\frac{1}{80}$. Iron does not whiten copper so much, in equal quantities, as tin does, and still less than arsenic.

[1 *Aikin*, 346.

Bronze, the name of a mixed metal, which the ancients employed for casting statues and other ornaments. According to Vasari, the bronze of the Egyptians consisted of two-thirds of brass, and one of copper; and Pliny informs us, that the Greeks added to the brass one-tenth part of lead, and one-twentieth part of silver.

In casting bronze figures, particular attention must be paid to the formation of the mould. The pattern from which the cast is to be made must have a mould made upon it, with a mixture of one-third of plaster of Paris, and two-thirds of brick-dust. Its thickness should be proportioned to the weight of the figure; and small air-holes, opening upwards, should be made in the joints, to give free passage to the air, which is thrust out by the entrance of the metal. Over the interior surface of the mould there should be spread neatly a layer of clay of the intended thickness of the metal. When this is done, the concavity, which is bounded by the layer of clay, is to be filled with the composition of plaster of Paris and brick-dust already mentioned, which will form the core. When the figure is long, strong bars of iron must be laid in the mould as a support to the metal figure, and round these the core must be cast. The mould is then opened, the

layer of clay taken out, and every kind of dampness expelled, by drying the mould and core with charcoal or lighted straw. The core is then replaced in the mould, where it is supported in its proper position by short bars of bronze, which run through the mould into the core. The mould being strongly fortified with iron bars, and fixed in a right position, the liquid bronze is poured into the mouth of the mould.

Bronzing, is the art of imitating bronze, or of communicating to figures in wood, ivory, plaster, &c. that greenish rust which distinguishes the bronze figures of the ancients. The golden bronze is made of the finest and brightest copper dust, and when it is wanted of a red colour, a small quantity of red ochre, well pulverized, is added. They are both put on with varnish, and the body to which they are applied is immediately dried over a chafing dish, to prevent it from turning green.

The following method of bronzing figures is extremely simple. After having covered the figure with a coat of gum water, mixed with a little minium,* take a little fish glue,† dissolved in spirits of wine,‡ by exposing them in a warm place, and add to it some saffron; then take the filings or dust of any metal which it is wanted to imitate, and apply this, when mixed with the glue, to the figure, with a hair pencil.

In bronzing copper, the Chinese first rub it with vinegar and ashes, till it is well polished. When the copper is well dried in the sun, they cover it with a coat, made in the following manner. Take two parts of verdigris, two parts of cinnabar, five parts of sal ammoniac, two parts of the bill and liver of ducks, five parts of alum; pound and mix them well, and form them into a clear paste. The copper, after being covered with a coat of this paste, is dried, cooled, and washed, and the same operation is repeated about ten times.

* Red Lead. † Isinglass. ‡ Or 4th proof brandy.

Iron may be bronzed merely by rubbing it when hot with the hoof of a cow, and with oil.—*Brews. Ency.*

The *Gong* is composed of 78 parts of copper and 22 parts of tin. The *Packfong* is copper and tin with about one-third of nickel.

Copper with Lead.

These metals unite to appearance very intimately by fusion, but, what is very remarkable, when a mass of this alloy is exposed to a heat less than that at which the whole melts, the lead alone sweats out, leaving almost all the copper in a porous or honeycombed state. When the copper holds a small portion of silver, the lead carries the latter out with it, and this is the principle of the old process of *eliquation*, formerly much used in the extracting of SILVER from copper ores. Copper with about a fourth of its weight of lead forms *pot-metal.* The ancient Roman pot-metal, according to Pliny, was composed of 100 of copper, 2 of lead, and 2 of tin. The same ingredients, but with more of the two latter, were the materials of many of the ancient Greek and Sicilian coins.—1 *Aik.* 347.

Ancient Weapons and Coins.

The ancient weapons both shields and swords were for the most part made of copper hardened with tin. I recollect but one place in Homer where iron is mentioned as the metal employed for the purpose, and that was the point of the spear, wherewith Pandarus wounds Menelaus. The word is, Sidèron. Il. 4. T. C.

Hardening Copper.—In the second vol. of this work, old Series, conducted by Dr. Coxe, is an account of Le Sage's method of hardening copper by phosphorus. The process will succeed, but when so hardened, the metal is so brittle as to be fit for no purpose whatever.

The same may nearly be said of the process of hardening and whitening copper with arsenic. Melt the cop-

per: cover it with charcoal: to two parts of copper by weight, add, tightly folded up in paper, one part of a mixture of equal weights of potash and arsenic fused together; putting in the arsenic when the potash is quite hot. As soon as you have thrust this to the bottom of the melted copper with a stick, cover the crucible quickly, and lute the sides of the cover. In a quarter of an hour, the mixture may be poured out. It will be hard, white, and very brittle. Where the latter quality does not spoil it, this alloy may be used, as a substitute for silver. Perhaps brass thus treated with arsenic, might be used to good purpose. T. C.

Plating.—This is confined to the covering of copper or brass, the metals usually employed for this purpose, with a plate of solid silver. The other methods of covering copper or brass with a still thinner coating of silver, is called *Silvering*.

Plating is thus performed. An ingot or bar of copper, previously well hammered to increase its ductility, and neatly cleaned and planished, is covered with a very thin coating of pounded and finely-sifted glass of borax: upon this, is laid a plate of silver from one-tenth to one-sixteenth part of the weight of the copper, according to the proposed value of the plated goods. The plate of silver is very nearly but not quite so large as the bar of copper. The silver is also planished, so that previous to the operation, the under surface of the silver and the upper surface of the copper may touch nearly in all their parts. The silver being laid on the copper, previously strewed very thinly with the sifted borax, a few blows with a hammer or mallet are given, to bring the surfaces still more into contact. The silver is then bound to the copper by iron wire drawn tight. The edges are also covered with powdered and moistened glass of borax so as to cement the silver, when heated, to the copper. They are then ex-

posed to a considerable heat approaching to, but short of melting. The very thin coating of interposed borax, assists in preventing any oxydation of the surface of the copper, while it is too thin to prevent the adhesion of the metals. The double plate is then passed through well polished steel rollers, till it be of the required thinness : the silver and copper being diluted by the pressure, equally.

An ounce of silver is often rolled out to a surface of about three square feet and its thickness does not exceed the three thousandth part of an inch. Hence the silver is easily worn off the sharp edges of plated copper : an inconvenience remedied to a certain degree of late years, by using for the edges of plated ware, copper more thickly plated than in those parts of the utensil not so much exposed to friction.

When plated candlesticks for instance, after long use, begin to shew the copper from the silver being worn off, it may easily and cheaply be renewed, by mixing the precipitate of silver from nitric acid by means of common salt with two parts in quantity of whiting, two parts of common salt, and two parts of cream of Tartar. Those who are not chemists may make this paste thus. Send to the druggists for a quarter dollar's worth of Luna cornea, or Lunar caustic : moisten it in a teacup and mix it into a paste with twice and even thrice its bulk of each of the other ingredients above mentioned. When the candlesticks are cleaned, either with the finger or a soft cork rub the parts where the silver is worn off: the copper becomes almost instantly covered with a coating of pure silver, thin indeed, but which can be renewed at a small expence. T. C.

French plating, is managed by the application of silver leaf to copper or brass well cleaned and planished and then heated quickly, so as not to allow time for oxydation.

The silver leaf laid on the heated metal, is then bur-

nished down. Successive coatings of silver leaf may be thus given.

Silvering, on copper and brass may be performed by the muriat of silver mixed with whiting, common salt and cream of tartar in the way I have mentioned. The whiting should be previously washed and the first coarse sediment permitted to subside: the sediment of the supernatant liquor should alone be used, either for this purpose or any purpose of cleaning silver or brass; because, the common whiting is apt to have gross particles of sand in it, that will scratch the surface.

Or, to a solution of silver in aqua fortis, add some clean plates of copper: the silver will be thrown down in a fine powder in its metallic state. Separate it from the surface of the copper, and wash it well. Of this powder take one part, common salt and sal ammoniac four parts by weight, corrosive sublimate one fourth of a part. Rub them well together in a mortar with a little water, into a paste. Clean the vessel to be silvered by any dilute acid, or by common salt and tartar: rub it with this paste till it acquires a metallic coating, which will be an amalgam of mercury from the corrosive sublimate with silver, produced by the triple action of the silver, the copper, and the mercurial salt. Wash the coated surface; then expose it to heat so as to drive off the mercury, and the silver remaining on the copper, may be burnished in the common way.

Or, mix 20 grains of silver precipitated by copper, 2 drachms of tartar, two drachms of common salt, and half a drachm of alum. This composition being rubbed on a clean surface of brass or copper will cover it with a coating of silver, which may be polished with soft leather.

Or, take half an ounce of silver precipitated by copper from aqua fortis: grind it up with two ounces of sal ammoniac, two ounces of common salt, and one drachm of

corrosive sublimate of mercury, into a paste. Boil your copper for half an hour in alum and Tartar; take it out, and rub it with this paste. Then heat it red-hot, and afterward polish it.

When buttons are stamped out of plated copper, the edges and backs will be coppery. To whiten them, they are boiled in water containing as much argol or tartar as it can hold, in which precipitated silver is also put. The backs and edges are thus whitened, in the same way that the brass wire of pins is tinned.

I believe iron is plated on the same principles with copper and brass.

I do not know that any body has yet attempted to plate copper with *platina* except Dr. Bollman. His iron plated with platina, is a very beautiful manufacture, and would prove highly useful for crucibles, and culinary vessels; but I do not know that he has yet succeeded in plating copper with platina by lamination, in the same way as silver is rolled on copper. But copper may be coated with platina by means of a mercurial amalgam, as has been proposed and tried on the continent of Europe. The process is thus.

M. Strauss in Gehlen's Journ. 20 Phil. Magazine, 285. Take a solution of platina precipitated by sal ammoniac: wash it: dry it: expose it to a red heat in a covered crucible for half an hour. This may be amalgamated with from five to seven parts of mercury by trituration in warm water. (Why not use the precipitate hot?) This amalgam laid over copper, unites with it, and the mercury may be driven off by heat as in the case of silvering or gilding with mercury. A second coating may be applied, mixed with chalk and sprinkled with water: the plate is again exposed to a red heat to drive away the mercury. The platina may then be burnished down.

Tinning Copper.—The common method of tinning copper vessels, is first to scrape the inside clean from any rust; then to rub them with sal ammoniac; or while warm with rosin or fat: then melted tin is poured on the copper and by means of a cloth whitened with whiting to prevent the hot tin adhering to and burning it, spread evenly over the surface of the copper, and then planished.

The common tin used for this purpose is usually adulterated with lead which has been supposed to be very deleterious, but some French experiments on the subject have shewn that it is less so than was imagined.

The following papers on the subject of tinning copper vessels are worth noticing.

New Process for Tinning Copper and other vessels in a durable manner.

That copper and brass vessels cannot be used with safety in cooking victuals or for holding articles of food, and particularly those which contain acids, is well known. It is also well known that the tinning applied in the usual manner is not durable, being soon worn away by cleaning, and on that account must be frequently renewed. Some, therefore, have proposed enamelling for kitchen utensils of copper; which, indeed, would answer exceedingly well, and be much safer for the health than impure tin mixed with lead, often employed for tinning; but, unfortunately, enamel is too dear, and readily breaks when the vessel receives the least blow; which cannot always be avoided.*

* Articles that would come high when made singly, may be afforded at a low rate when manufactured on an extensive scale.—Cooking utensils lined with a vitrified glazing, are now commonly sold in many shops in London, and at a moderate price. It would be as reasonable to object to the use of earthen-ware or China, because they may be broken by blows, as to make this an objection against the use of glazed kettles.

The following process for tinning is attended with no danger from poisonous ingredients, as no lead is used in it; the tinning, too, is exceedingly durable, adds strength to the copper vessel, and secures it from the action of acids much longer than the common tinning:—When the vessel has been prepared and cleaned in the usual manner, it must be roughened on the inside by being beat on a rough anvil, in order that the tinning may hold better, and be more intimately connected with the copper. The process of tinning must then be begun with perfectly pure grained tin, having an addition of sal ammoniac instead of the common colophonium.* Over this tinning, which must cover the copper in an even and uniform manner throughout, a second harder coat must be applied, as the first forms only a kind of medium for connecting the second with the copper. For this second tinning you employ pure grained tin mixed with zinc† in the proportion of two to three, which must be applied also with sal ammoniac smooth and even, so that the lower stratum may be entirely covered with it.

This coating, which, by the addition of the zinc, becomes pretty hard and solid, is then to be hammered with a smoothing-hammer, after it has been properly rubbed and scowered with chalk and water, by which means it becomes more solid, and acquires a smooth compact surface.

Vessels and utensils may be tinned in this manner on both sides. In this case, after being exposed to a sufficient heat, they must be dipped in the fluid tin, by which means both sides will be tinned at the same time.

As this tinning is exceedingly durable, and has a beautiful colour, which it always retains, it may be employed for various kinds of metal instruments and vessels which it may be necessary to secure from rust.

* Rosin. † See the next paper.

Another durable, though somewhat expensive, Method of Tinning.

This tinning, which consists of more articles and is dearer than the former, can be applied to metals and metallic mixtures, and, when well prepared, is exceedingly durable; which makes up, in some measure, for the cost. It is as follows.—Take pure grained tin one pound, good malleable iron one ounce and a half, platina one dram, silver twenty-four grains, and gold three grains. These five metals must be well fused together in a crucible with one ounce of pounded borax and two ounces of pounded glass, and the liquid matter must be formed into small ingots. These ingots are to be again heated and reduced to powder in a warm mortar with a hot pestle. This powder is then to be put in an iron pan over the fire, where it must be again fused, stirring it well round: it is then to be poured into small flat moulds, where it is suffered to cool, and it is then fit for use.

This tinning is to be applied in the following manner. First tin the vessel with grained tin and sal ammoniac in the common manner; clean and scower this coating; then apply the composition with sal ammoniac according to the usual process, and when it is well diffused suffer the vessel and the tinning to cool. Then expose it every where to a gentle heat to render the adhesion stronger, and immerse it while hot into cold water to give it that hardness and solidity which it had lost by being heated. The surface is somewhat rough and gritty: but you then rub it hard with a scratch-brush; and, in order to make it even, you afterwards smooth it completely with fine sand or any polishing ingredient.

If one coating does not appear sufficient, a second, and even a third, may be applied in the manner above described. Two coatings, however, are fully sufficient for kitchen utensils which have been a good deal used; and

if you wish to have the surface perfectly smooth and even, you may apply a thin coating of tin, which will fill up all the cavities and render it quite even. A coal fire is the best for this tinning; for turf coals attack the metal, and interrupt the union and fusion of the coating.

[7 *Tilloch*, 218.

Extract from a work, published by Professor Proust, *entitled Researches on the Tinning of Copper, on Tin Vessels, and glazed Pottery; published at Madrid*, 1803.

THE author, in the introduction, says, that the motives which induced him to undertake this labour were the doubts spread abroad, two years before, among the public in regard to the salubrity of tinned copper, and the accounts of the disagreeable accidents arising from vessels badly glazed. Government, always attentive to every thing that can tend to calm the public mind, had recourse on this subject to sound chemistry; the only tribunal competent to banish doubts of this kind. Two problems were presented to the author to be resolved:

1st, Is the use of zinc advantageous or not, for tinning and for tin vessels?

2d, Can tinning, in consequence of the lead it contains, and sometimes in large quantities, expose the health of the public to the same dangers as glazing of a bad quality?

The author divides his work into three chapters, and each chapter into several paragraphs.

The first part, which may be considered as historical, is divided into four paragraphs.

In the first the author mentions the project which was presented by M. Malouin to the Academy of Sciences at Paris in 1741, in regard to the employment of zinc for tinning iron and copper; the advantages he promised

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himself were only illusory, and his expectations have not been confirmed by time.

The second paragraph contains an account of a paper on tinning, presented to the same academy by J. B. Kemerlin in 1742. One may see there the examination of it by Messrs. Hellot and Geoffroy, who entertained an opinion contrary to the assertions of the author.

The same year the academy charged Hellot and Geoffroy to examine the alloys of zinc proper for making vessels. The inconveniences pointed out by the two academicians, as well as by many others, were verified by Proust; and all of them are inclined to proscribe such alloys. Having made a mixture of equal parts of lead and zinc, similar to that examined by the two commissioners, he obtained an alloy of a paste-like consistence, as easy to be cut with a knife as cheese, and difficult to be cast. M. Pierre Blanco, a very ingenious pewterer, seconded the labours of Proust. The first time he poured the alloy into the mould, it did not run sufficiently to fill it. He tried it a second time; and, when he thought he could draw it from the mould, it fell into pieces, as they had no cohesion. Being desirous to procure a piece well or ill moulded, he found himself obliged, at the third time, to cool his mould in cold water, and to employ double the time necessary to cast a piece of the same size with common alloys: the vessel obtained broke short, and was filled with defects which could not be remedied. A pound of alloy was employed, and the article weighed only nine ounces. The whole of the residuum was mere loss. The same article acquired in a month a dark colour, and at the end of six months was covered with oxyd; inconveniences which do not take place in vessels of common tin. The author still continues to make several practical objections, to which no one has given an answer.

It is seen, therefore, that alloys of zinc are not so advantageous as some have imagined; and those who propose them have neither consulted chemistry nor practice. Before they were presented to government for its sanction, it was necessary to subject these alloys to the test of chemical agents: and this the author has not omitted.

1st, A plate of the alloy in question being brought into contact with vinegar, the latter contracted a very disagreeable metallic taste at the end of a day: on the third day, without being sweet, astringent, or bitter, it occasioned in the throat a very uneasy and disgusting sensation, and no doubt a small dose of it would have excited vomiting.

2d, A plate of the same alloy, of four inches' surface, boiled half an hour in vinegar, lost 16 grains of its weight.

3d, Vinegar being boiled in a vessel tinned with the same alloy, acquired the same taste as No. 1.

4th, A plate of the same alloy, exposed cold in distilled vinegar, exhibited the same phænomena as No. 1 and 3. This solution, when attentively examined, did not exhibit an atom of tin.

All these facts, which confirm those of the French academicians, prove that zinc is a metal exceedingly soluble in vinegar, very easily altered, and that solutions of it having been found noxious, it ought to be proscribed from our kitchens.

The subject of the third paragraph is the project of M. Doucet, who in 1778 presented to the Academy of Sciences at Paris a bar and pan made with a mixture of his invention. It was examined by Macquer and Montigni, who made a report on it. These two chemists, having more experience than Hellot and Geoffroy, analyzed it chemically, and, having soon found that it had its inconveniences, it was rejected.

The alloy of Chartier, and the project of Lafolie, shared the same fate, as is seen by the report of the commissioners, and by the labours of the abbe Monges and of Bayen.

The alloy of M. Buschaendorf, of Leipsic, presented in 1802, and described in the *Annales des Arts et Manufactures*, forms the subject of the last paragraph. Proust subjected it to the same experiments as the preceding: he proves that it is attended with the same inconveniences, without having any of the qualities announced by Buschaendorf

Part II.

On the Old Method of Tinning.

This part consists of ten paragraphs. M. Malouin, while he proposes his mixture, does not condemn the old, but he mentions the dangers to which people are exposed by this kind of tinning. Kemerlin, Hellot, Geoffroy, Doucet, Chartier, Lafolie, Buschaendorf, and others, have done no more: but no one has hitherto proved the reality of these supposed dangers; and what is still more astonishing is, to see the inactivity of the chemists of Europe in realising or exploding a fact which is so interesting to society. To decide the question in a peremptory manner, it was necessary to undertake a series of experiments which had before been neglected. To succeed in them it was previously necessary to examine the properties of some metals and oxyds; and there are nine paragraphs employed in the examination of iron, antimony, mercury, lead, and zinc. This examination was requisite to answer all the objections which he proposed to resolve in the third part of this work.

Part III.

This part is divided into five paragraphs.

Paragraph I.

Experiments made on the Old Method of Tinning.

Five plates of copper each a foot square, were tinned, all the necessary precaution being taken. The object of

the author was to ascertain the quantity of alloy they would take one with another.

The first took	-	144 grains
The second	-	178
The third	-	200
The fourth	-	208
The fifth	-	230

The quantity of tinning which copper can take is exceedingly variable, and not subject to calculation: the alteration of the copper by tinning being in all points the same, the variations in the weight must necessarily depend on the more or less exact manner in which the workman removes the superfluous tinning; and one might be induced to believe that the artist has it in his power to give a tinning more or less abundant; but the tinning not alloyed with the copper ought not to be considered in the same manner as that which is alloyed. The author has proved, in general, that good tinning takes a grain of tin per square inch.

Paragraph II.

On the Duration and Causes of the Destruction of Tinning.

Tinning with pure tin has a silver white colour, and, in contact with vapours capable of attacking it, assumes a yellowish tint. That made with one-third, one-fourth, or one-half of lead, like the old tinning, has more brilliancy, and may be easily distinguished from the former.

The causes which destroy tinning are friction, caloric, and acids: the effects of all these causes vary according to an infinite number of circumstances, which are determined by the author as exactly as possible, and have taught him, that, even supposing alloy to be made with one-half lead, no individual can swallow per day 1-20th grain of that metal; a quantity inappreciable in its effects,

since we daily swallow a hundred times more when we eat game, without being incommoded by it. From these facts, and many others, it results, that if vessels of tinned copper occasion illness, they ought rather to be ascribed to the want of tinning than to the latter.

Paragraph III.

Of Tinning considered as soluble in alimentary Acids.

Eight saucepans, each capable of containing twenty ounces of water, were tinned with the following alloys:

The 1st, with pure tin.
2d, with tin having 0.05 of lead.
3d, - - 0.10
4th, - - 0.15
5th, - - 0.20
6th, - - 0.25
7th, - - 0.30
8th, with equal parts of tin and lead.

Tinning with pure lead was impossible.

Into each of these pans there was put a pound of red wine vinegar, which was boiled till it was half consumed. The vinegar of each pan was poured into a glass vessel, and suffered to remain at rest for twenty-four hours. The vinegar was then poured off, and the precipitates were well washed: each portion of vinegar was mixed with an equal quantity of distilled water; equal parts of each were put into the vessels, and three rows were formed of eight vessels each. The vessels of the first and second rows contained vinegar; those of the third, sediments. Nearly four ounces of the sulphat of potash were poured into each vessel of the first row, and into those of the second and third row about four ounces of hydro-sulphurated water. In the first row no precipitate was observed, consequently there was no lead: in the vessels of the second row there was observed a slight chesnut-coloured sedi-

ment, which indicated the existence of tin. The sediments of the third row did not change colour, whence it was concluded that there did not exist in them any metallic substances. The vinegar, then, boiled in the tinned pans did not dissolve lead, but only a very small quantity of tin.

The sediments of the third row were, for the most part, composed of tartar and sulphat of lime. These two salts, in precipitating, might have carried with them a little lead; but they did not contain an atom of it.

The same experiments being repeated with very strong white wine vinegar, which was boiled till three parts of it were consumed, confirmed the preceding facts; with this only difference, that the tinning assumed the colour of lead, and readily yielded to the friction of the finger, coming off in the form of a gray powder, which was nothing else than very fine particles of lead. This phænomenon was more remarkable in the pan No. 8, though the quantity of that powder did not weigh half a grain. These facts were the less remarkable the nearer to the pan No. 1; so that with a little practice one might judge by these means of the quantity of lead and tin contained in tinning.

The vinegar formed zones of a very beautiful colour on the tinning of the pan No. 1. These facts may still serve to enable one to distinguish the quality of tinning. These experiments evidently prove that lead, which is very soluble in vinegar, loses that property when alloyed with tin. This is agreeable to chemical facts already known; for tin is more oxydable and soluble than lead, and the latter is precipitated from its solutions by tin, and this is the cause of the presence of the gray powder above mentioned; for vinegar, indeed, dissolves immediately a few particles of the lead in the tinning, but it is afterwards precipitated by the tin, and forms gray dust. All these facts, and many others explained by the author,

prove that tinning, the half even of which is lead, cannot be dangerous in domestic purposes; and that, to be hurtful to the health by the contact of alimentary acids, it would be necessary that the pans should be pure lead, or tinned with that metal only, which is impossible.

Paragraph IV.

On Tin Vessels.

It was necessary to examine the action of vegetable acids on vessels of tin. For this purpose the author caused the following vessels to be made:

1st, Pure tin.
2d, Tin having - 0.05 of lead.
3d, Ditto - - 0.10
4th, Ditto - - 0.15
5th, Ditto - - 0.20
6th, Ditto - - 0.25
7th, Ditto - - 0.30
8th, Ditto - - 0.50
9th. Of pure lead.

All these vessels were filled with boiling vinegar, which was left in them three days. The vinegar of the first eight vessels being subjected to the examination of reagents, did not give the least signs of the existence of lead, but of some particles of tin. The vinegar in the ninth vessel was much saturated with lead.

The same experiments, repeated at three other times, with vinegar of greater or less strength, exhibited the same phænomena. In these cases it was observed that the first eight vessels had assumed the colour of lead, and exhibited the same phænomena as those indicated in regard to tinning in the preceding paragraph.

The author, after supporting his observations by those of Bayen and those of Vanquelin, deduces this consequence: Tin alloyed with lead is harder than when it is pure, and less susceptible of suffering its particles to be

mixed with aliments. What have we to fear from such vessels? Small particles which may be detached by the fork or the knife? Such fears are groundless. Let us apply, then, to vessels of tin, in regard to their use, what we have said of tinning, that the fears entertained in regard to the employment of it are not proved by any facts well authenticated; and if the art of the pewterer is susceptible of improvement, either in regard to health or practice, it cannot be expected from mixtures which have always been rejected by sound chemistry. Besides, we know several other mixtures which might be tried before we have recourse to a metal so soluble, and so difficult to be worked, as zinc.

Let us now form a parallel of the alloys we have examined, with those used by the pewterers.

Pure tin forms the first quality, which they employ for the best utensils and those most esteemed.

The second kind of mixture contains an eighth of lead, and serves for making common vessels.

The third kind contains 0.15 of lead, and is employed for drinking-vessels.

The first kind, which is the most common, contains 0.20 of lead, and is employed for making ink-stands and other small articles.

From what has been said it may be seen, that if pewterers employ sometimes for common vessels the fourth kind of mixture, the public can be exposed to no danger. The ancients, who made so much use of tin vessels, have left us no certain facts which prove that the use of them was contrary to health, and medicine never proscribed them.

[21 *Till.* 313—319.

To Separate Copper from Silver, by M. Goetling.

Four methods are known for separating copper from silver, in all of which the alloy is dissolved in the nitric acid. As the price of this acid is high, M. Goetling, in

place of it, employs sulphuric acid, which is much cheaper. His process, which has fully answered his expectation, is as follows:

The proportion of silver in the alloy is first to be ascertained by the touch, or in any other way. For each part of silver one part of sulphuric acid, and for each part of copper three and three-fifth parts of the same acid, are to be taken. The acid, diluted with half its weight of water, is to be poured into the matrass on the alloy, reduced to small pieces. An addition of one part more of the acid to every sixteen parts of the alloy facilitates the solution. Place the matrass in a sand heat, and bring the contents to a state of ebullition. If care be taken to stir it frequently with a glass rod, the alloy will be broken down and converted into a sulphat in two or three hours. It will become thick, and sometimes hard. While still hot, six or eight times its weight of boiling water is to be added to it, and the heat to be continued for some time. By this means the sulphat will be dissolved, and a great part of the sulphat of silver will be precipitated. When the whole is found to be completely dissolved, a clean plate of copper, or a few pieces of clean copper money tied loosely in a coarse cloth, is suspended in the fluid, and the boiling is continued for some hours, by which means all the sulphat of silver is decomposed, and the metal separated in a metallic form.

To ascertain when the separation is complete, a small quantity of the solution is taken out and tried, by adding a few drops of a solution of muriat of soda. If a curdly precipitate is formed, it is a proof that some of the silver still remains in it; in which case the boiling must be continued.

When a complete separation is effected, the clear solution is to be decanted off with care, and the precipitate washed. To ascertain that all adhering sulphat of copper

is removed, drop into the water last poured off from the precipitate a few drops of liquid ammonia. If any of that sulphat be still present, the ammonia will produce a blue colour in the water. The silver, if not wished to be kept as a powder, may be melted with from a fourth to a half of its weight of nitrate of potash.

The liquid sulphat of copper decanted from the precipitate, as also the water employed in washing it, may afterwards be evaporated in a copper basin, and, by crystallization, a quantity of blue vitriol equivalent to the cost of the acid will be obtained.

Should some parts of the alloy, by accident, have remained undissolved, they may be separated by decantation, and reserved for the next repetition of the process.

[21 *Phil. Mag.* 352,

This process is somewhat of a kin to that discovered by James Keir, Esq. of Birmingham. Take 10lbs. of oil of vitriol: dissolve in it 1lb. of nitre. This mixture will in a moderate warmth or even in the temperature of a warm day, dissolve silver, when undiluted: it will not dissolve gold, platina, iron, zinc, or nickel, unless it be diluted. This is an useful, because a cheap process. Aqua regia made with nitric acid is dear comparatively.

ON ROLLING COPPER INTO PLATES.

The following method of rolling Copper into plates, as practised at the extensive works at Taybach, in Wales, is taken from Donavan's Tour through South Wales and Monmouthshire.

BEFORE the copper is converted into plates or bars, the pig of metal is made red hot, when it is closely beaten together under the hammer, and cut into pieces of the most convenient length for the purpose wanted, by shears moved by a wheel. Again, those pieces are conveyed to the furnace when they become red hot as at first. One

of the pieces is carried at a time to the flatting mill, a machine not much unlike the rolling press of a copper plate printer. The two cylinders are of steel, case-hardened and secured within a frame of iron. A man stands on each side, and while the two cylinders revolve, each in a contrary direction, one of them lifts up the piece of red hot copper with a pair of tongs, and thrusts it between the cylinders, the other man on the opposite side securing it with his tongs as it passes through. This he lifts back again over the upper roller to the first man, who by the assistance of a strong screw, diminishes the distance between the two cylinders, in order to widen and compress the plate still more; when it is conveyed a second time between them. This screw is turned for the same reason every time before the plate passes between the cylinders, and thus by the most simple process imaginable, the plate is gradually reduced as thin and broad as the workmen may desire.

By means of a similar machine, the copper is wrought into bars instead of plates, of any form or thickness, with equal facility. For the latter purpose, the smooth surface of both the cylinders are alike indented with eight, ten, or more distinct grooves, all which differ from each other in width and depth. The series commences with the largest groove, encircling one end of the cylinder; the next in point of size succeeds, and thus they diminish gradually to the other extremity of the series, which terminates with the smallest groove. The piece of copper being heated as before to a fiery redness, the workmen force it between the first or largest groove of the adjusted cylinders, where it receives either the round or angulated form of the groove from the compression of both the cylinders, as readily as wax in a common mould. Should it be necessary, the bar is conveyed in like manner progressively through the second, third, or fourth groove, or

through the whole series, till it is reduced to the thickness wanted, the length being increased in proportion as the bulk diminishes.

The copper, after receiving its proper form in the flatting mills, and cooling, is of a dusky black, or iron colour, and in order to communicate to it that lively hue which is commonly understood to be the true complexion of this metal, the plate or bar is heated again for the last time in a furnace, and when red hot is plunged into a recess filled with a saline liquor,* where it assumes that colour in a few moments, and being withdrawn, the copper is put aside as being finished for exportation.

[3 *Archives*, 14.

To Separate Copper from Silver.

SIR—I intended to have deferred the present communication till such time as I should have it in my power to lay before the public the complete series of experiments in which I have been engaged with regard to the purification of gold and silver. But unluckily I mentioned a few particular circumstances with regard to them, to a man who took it upon him, without my knowledge, to send an account of them for publication to a periodical work. As I understand that work will not appear so soon as your next number, I beg, if you think it worthy of a place, that you will insert the following account of some attempts I have been making to purify the precious metals.

Being much at a loss for the want of a crucible of pure silver for the analysis of some minerals, and as all the usual methods practised for purifying that metal are very troublesome, I set myself to consider the various operations on metals, in hopes of falling on a more simple way

* In Aikin's Chemical Dictionary, it is stated, that this fluid is urine. The redness which the copper thus acquires, is considered by the merchant as one mark of the purity of the metal.

of accomplishing my purpose. At length, I found a process of Pelletier's, which promised to succeed, and mine is merely extending his idea a little further than he did himself.

He was, I believe, employed by the French government to discover an easy way of separating the tin from copper on bell-metal, and the process he gave, is this. Upon the melted bell-metal project black oxyd of manganese in powder, frequently stirring the metal till all the tin becomes oxydated by the manganese. He adds a caution, not to add too much manganese otherwise part of the copper also will be destroyed.

It immediately struck me, that in this way I might be able to oxydate the copper which alloys our silver, and upon making the trial I succeeded completely: I had some impure silver rolled out to about the thickness of a shilling, this I coiled up spirally, and put into a crucible, the bottom of which was covered with black oxyd of manganese. I then added more oxyd till the silver was covered, and all the space between the coils completely filled. A cover was then luted to the crucible, and a small hole left for the escape of oxygen gas. When this had been exposed for a quarter of an hour to a heat sufficient to melt silver, I found the surface of the manganese brown from the loss of oxygen; but, where the silver had been, the whole was one uniform black powder, without the least appearance of metallic lustre, so that I had no doubt, that even the silver was become an oxyd.

I then put the whole contents of the first crucible into a second of a larger size, into the bottom of which I put a quantity of pounded green glass, about three times the bulk of the contents of the first crucible, and luted on a cover as before, to prevent the access of any inflammable substance.

The crucible was then exposed to a heat sufficiently strong to melt the glass very fluid. Upon cooling and breaking the crucible, I found the silver at the bottom perfectly pure, as its oxyd alone could part from its oxygen without the access of some inflammable substance. I find this process answers equally well for purifying gold, and to me it seems to possess some advantages over all the former methods. The materials used are cheap, and a large quantity can be refined as soon and as easily as a small quantity, by merely altering the capacity of the crucible you use.

I tried the same operation on gold and silver in round masses, but found it went on very slowly, and what I scarcely expected, in the first part of the process of oxydating the metals, the remaining metal continued uniformly impure or nearly so, until the whole was oxydated.

I regret that I have been forced to make this matter public, before I could do it in a manner satisfactory to myself. I wished to have given the exact proportions of alloy, manganese, and glass to be generally used, and to have ascertained if there is any truth in the old opinion, that saltpetre melted with gold destroys a part of it. I suppose that idea may have arisen from the oxygen given out by the nitre in a high heat, oxygenating the copper contained in the impure gold, which has been the subject of the experiment.

Since the above was written, I have been informed that this matter has actually been published, but know not in what work. I hope you will still have the goodness to insert this as an *original communication*, as I do not think the person who has published it will have the impudence to call it his own, and as Mr. Kirwan, and other celebrated chemists long ago advised me to publish it, I have already stated my reasons for not following such good advice.

As I have now been forced to appear before the public, I have hopes I shall be able to prevail on some of my friends to commit themselves in the same way, in the confidence that their labours will be found useful to the public.—I am Sir, your's truly,

ANDREW THOMSON.

Banchory, by Aberdeen, May 5th, 1805.

[11 *Nich. Jour.* 125.

Observations on the Metallic Composition for the Specula of reflecting Telescopes, and the manner of casting them: also, a Method of communicating to them any particular Conoidal Figure: with an attempt to explain on scientific principles, the grounds of each Process: and occasional remarks on the construction of Telescopes. By the Rev. JAMES LITTLE.

There are but few things produced by the united effort of mechanical artifice and intellectual labour, which have done more honor to the ingenuity and invention of man, than the reflecting telescope; which has many advantages over any of the dioptrical kind, notwithstanding their improvement by acromatic glasses. It will bear a greater aperture, and may be made to magnify more, (as being more distinct,) in proportion to its length, than the others, as they are at present made; and its dimensions and powers are unlimited. What its excellence is, espepecially the Newtonian construction of it, has been proved by Dr. Herschell, to his own honor, and that of the age, and country, and patronage, which encouraged his labours. Accordingly, the persons, eminent for science and mechanical ingenuity, appear to have felt a peculiar and disinterested pleasure, in contributing to its improvement; and the late discovery of a metallic composition for the mirrors of it, which will bear as high a polish as glass, reflect as much light as glass transmits, and endure al-

most equally well, without contracting tarnish, is a farther encouragement to prosecute its improvement to perfection.

Among others, I had formerly, from admiration at its contrivance, bestowed some attention on the mechanism of this instrument: and, as it would have spared me some expence of time and trials, if any other person had previously suggested to me the hints, which I am to relate, I imagine they will be of use to others, in directing or assisting the course of their labour, in the same pursuit. I had also taken some pains, to understand the merits of the different constructions of this telescope: but, as this enquiry ended in a conviction, that the Newtonian form of it is the most perfect that can be hoped for; (it being the nature of its great author to persevere in his researches, till he had arrived at a complete solution of his doubts, and comprehension of the subject;) so I have only to report what resulted from my experience in the mechanical fabrication of it, as to the method of casting the mirrors, and communicating to them the proper figure.

Before I had heard of the improvements of the Rev. Mr. Edwards, in the composition of the specula for telescopes, I had made many experiments myself with that view; which lead me to give full credit to his report of the superior excellence of that composition which he recommends: because I had found, that the qualities of hardness, whiteness, and indisposition to contract tarnish, necessary to a speculum, could not, by any admixture that I could hit upon, be produced, unless the metal were so highly saturated with tin, as to be excessively brittle; and because I found that this brittleness, however inconvenient in some respects, was necessary to render it susceptible of the highest polish: for no metal yet known, except steel, (which, from its disposition to rust, is unfit for

this purpose,) will take as high a polish as glass will, unless it be more brittle than glass. And indeed this property is common to all substances which we know, that are capable of such polish: they must be very hard, and, as such, brittle; for the polishing powder employed would stick and bed itself in any soft metal, instead of cutting and polishing it.

From the result of my trials, I contented myself with the composition mentioned hereafter, as being in every respect sufficient for the purpose, and inferior to none in whiteness, lustre, and exemption from tarnish: for, as to the addition of silver, I found that, when used even in a very small quantity, it had an extraordinary property of rendering the metal so soft, that I was deterred from employing it: and unless it shall be found that, without this effect, it makes the metal less porous than otherwise it might be, or less frail and brittle, I am certain that it may, in every other respect, be dispensed with. I had no opportunity to try it, in the precise quantity Mr. Edwards recommends, (though I did so before, in very nearly that proportion, since I first saw his memoir on that subject. Sir Isaac Newton made trial of a very small portion of it, and found the same effects from it as I experienced: but it is possible, that, if it were added in the just proportion discovered by Mr. Edwards, it would be an improvement, and useful ingredient, in the composition.*

* Having read somewhere, that zinc and gold made the best speculum-metal, I tried it; and found, that the zinc was sublimed from the gold in fusion, and arose to the top in the crucible forming a white, hard, spongy mass. The metal, called tutanag, is fit for specula, when melted with tin; but I am certain, that what I procured, under the name of tutanag, was a mixture of brass and copper, &c.; for the zinc, in the brass, rose from it, during the fusion, in white flowers.

I must observe here, that a metal, not liable to contract tarnish from the air, is otherwise susceptible of it accidentally: when there happen to be minute holes in its surface, caused by the air, or sand, &c. in casting it. Such cavities will be filled with the dust, or rusty solution of the brass, in grinding; which will, in time, become a sort of vitriol, and act on the contiguous parts of the speculum, producing a canker in it, which will spread in form of a cloud of tarnish, around each cavity. In such a case, to prevent this, I would advise, to lay the mirror, as soon as polished, in warm water, and, after drying, while it remains heated, to rub it over with spirit-varnish, from which it may be cleansed, by a piece of fine linen dipped in spirit of wine. The varnish will remain in the cavities; and, by defending the impurities in them from the action of the air, will probably preserve them from becoming corrosive to the metal.

From numerous experiments, of the qualities of different compositions, made by several persons, it appears, that no combinations, of any other metals or semi-metals, are fit for specula, except those of copper, brass, tin, silver, and arsenic. I tried no semi-metal, except the latter, which whitens copper, and unites intimately with it: because it is stated, in the treatise of the *Art of Assaying*, by the observant and accurate *Cramer;* that all the semi-metals rise in flowers, during the fusion: which would certainly make the metal porous. On this account, I would have rejected the brass, because of the zinc contained in it; but that it seemed to render the composition whiter, and less apt to tarnish, than it would be without it. It will have little tendency to rise in flowers, if the speculum, metal be fused, with the lowest heat requisite, and if the brass be of the best kind; because, in this, the zinc is more perfectly united with the copper, and both are purer. I used, for this purpose, the brass of pin-wire:

and, because the quantity of it was only the one-eighth part of the copper employed, which, I imagined, would receive too fierce a heat, if put alone into the melted copper; I first added to the brass, in fusion, about an equal quantity of the tin, and put the mass cold into the melted copper; supplying afterwards the remainder of the tin, and then the arsenic; the whole being generally in the following proportion: viz. 32 parts best bar copper, previously fluxed with the black flux, of two parts tartar, and one of nitre, 4 parts brass, 16 1-2 parts tin, and 1 1-4 arsenic. I suppose, with others, that, if the metal be granulated, by pouring it, when first melted, into water, and then fused a second time, it will be less porous than at first.

In this process, whatever metals are used, and in what proportions soever, the chief object is, to hit on the exact point of saturation of the copper, &c. by the tin. For, if the latter be added in too great quantity, the metal will be dull-coloured and soft; if too little, it will not attain the most perfect whiteness, and will certainly tarnish. It is too late to discover the imperfections of the metal, after the mirrors are cast and polished; and no tokens given of them (that I know) are sufficiently free from ambiguity. But I observed the following, which proved, in my trials, at first view, indubitable marks of the degree of saturation; and I think it fit to describe them particularly, as they have not, to my knowledge, been noticed by others.

When the metal was melted, and before I poured it into the flask, I always took about the quantity of an ounce of it, with a small ladle, out of the crucible, and poured it on a cold flag; and observed the following appearances:

First. If the metal assumed, in cooling, a lively blue, or purple colour, commonly intermixed with clouds, or

shades of green or yellow; and if, when broken, the face of the fracture exhibited a silvery whiteness, as bright and glistening as quicksilver, without any appearance of grain, or inequality of texture; then the degree of saturation of the metal, with the tin, was complete and perfect.

Secondly. If the surface of the metal became of a dun or mouse colour, and especially if of a brown or red; and when broken, the fracture exhibited a more yellow, or tawny hue, than that of quicksilver; then the quantity of tin in the composition was deficient, and it was necessary to add more.*

Thirdly. If the colour was an uniform dull blue, like lead, where broken, discovered a dull colour, with a coarse grain, like facetts; the due saturation was exceeded, and there was an over proportion of tin in the metal.

These colours would be more distinct, if a small quantity of the metal were cast in a flask, which had been previously smoaked, by a candle, made of resin mixed with tallow in which way I used to prepare the moulds. I attribute the formation of the colours to this: that, as the calx of every metal has its own peculiar colour, so, the heat of the melted mass, calcining some of the particles on its surface, which are in contact with the air, these display the colour of the calces of those ingredients which prevail in the composition. Whence, it may be expected, that, if the copper is the redundant metal, the mass will exhibit a reddish tinge, which is appropriate to

* This can always be done by degrees, and without any trouble, till the point of saturation is found; whereas, if too much tin were added at first, there would be a necessity for melting more copper separately, and repeating the whole process: and different specimens of copper will require different proportions of tin; so that the due quantity can never be known, *a priori*, but on trial only.

the calx of copper; and, if the tin be prevalent, a blueish die ought to appear. Either of these colours, therefore, appearing unmixed, shews the redundance of that metal, to which each belongs. And, as brass, when cast alone, has always a yellow tinge, so, when these three colours are exhibited in a cloud-like mixture, they shew an equality and due proportion of their respective metals in the composition. When too large a mass of the metal is cast together, its intense and lasting heat calcines the surface so deeply, as (when exposed to the air) to obscure the colours; so that a small quantity will best serve to exhibit them.

As to the method of casting the mirrors, it has been directed, to leave the ingate, or superfluous part of the cast, so large, as to contain a quantity of metal, equal to that in the mirror itself; which would occasion a great waste of it, and render it not easy to cast, at once, more than one mirror in each mould; and even this might be done so injudiciously as not to afford security against a miscarriage of the cast. But it will appear, that this great quantity of metal and incommodious manner of casting it, are by no means necessary. However, a judgment cannot be formed, of what may be the safest and most eligible method for casting the mirrors, unless it be considered, what are the circumstances attending this operation, in the case of malleable metals; and how the management of speculum-metal, in this respect, must differ from that of them: since there must be peculiar difficulty in casting, in sand, a metal more brittle than glass.

When any fused metal is poured into the flask, the external parts of it, which are in contact with the mould, congeal and harden sooner than the internal parts, and form a solid shell, filled with the rest of the metal, in a fluid state. This will, consequently, remain in a state of greater expansion, from its heat, than the external crust;

and its particles will, in the act of shrinking as it cools, recede from one another, as being more easily separable, and cohere, on each side, with the particles already fixed and grown solid: by which means a vacuum will be formed in the middle, and this will be gradually filled by the superincumbent metal, which has been later poured in, and remains longer in a fluid state. But, when there is no more metal supplied, the void, which was in this way latest formed, remains unfilled; and then the shell of the metal, adjacent to the vacuum, as yet remaining soft, and unable to bear the weight of the atmosphere, resting on it, sinks, and is pressed down into the vacuum: by which means, a pit or cavity will be constantly and necessarily formed in the face of the cast, in that part of it which was last congealed; which cavity will commonly be larger or smaller, in proportion to the quantity of metal in the cast.

The event will, in this respect, be the same with speculum-metal, as it is, in the case of that which is tough and malleable: only that, as the former, in cooling, arrives sooner at its natural state of hardness and brittleness, its external solid shell will not bend, but break, and fall into the void part under it; and thus form cracks, or abrupt chasms, in the places, where tougher metals would contract only regular depressions. And also, when the body of the cast is small, or the mould is so damp or cold, as to congeal, not only the surface, but the substance, of the cast too soon, and thus prevent a gradual influx of the fluid metal, to keep the central part as distended, as the exterior shell was, when it became fixed; the farther contraction of the interior parts of this brittle, refractory metal, after it has become solid, will be apt to form rents in it, because its substance will not bear extension, without rupture.

It would be an obvious remedy of the above inconvenience, if there could be contrived a reservoir of fluid metal, to descend into the interior part of the cast, and fill up the void made in it, as fast, and as long, as it is forming by the contraction of the metal. Now, this is effected, by having a jet or appendage to the cast, of such a size, form, and position, as will be effectual to retain the metal, composing it, in a state of fluidity; and also to suffer it to descend into the interior of the cast, until all parts of the same become fixed, and incapable of receiving any farther influx of metal. For thus, all the imperfections, that would otherwise be in the cast itself, will now exist only in the appendage to it, which is a supernumerary part, to be afterwards separated from it. This appendage ought to be of the form of a prism, and as nearly that of a cube, as the operation of moulding it in the sand will permit; for, in this gross shape, the metal in it will be the longer cooling. It should be connected with that part of the mirror, which is uppermost in the flask, and joined to it by a neck, equal in thickness to the edge of the mirror, (but so posited, that the face of the mirror may project a little above it), and, in breadth, about twice the thickness. This neck ought to be as short as possible, i. e. just so as to permit it to be nicked round with the edge of a file, in order to break off the prism from the mirror when cast: for thus the heat of the large contiguous body of the prism will keep the neck from congealing; which, if it happened, would stop the liquefied metal, in the prism, from running down into the mirror. And, to prevent this, the prism ought not to form directly a part of the main jet or ingate, by which the metal is poured into the flask; for so the jet would cool sooner than the large mass of the mirror, and bear off the weight of the atmosphere, which ought to press on the fluid metal in the prism underneath, and force it down into the mirror, to fill up all vacuities

in it. Both the prism and the mirror, therefore, ought to be filled by a lateral channel, opening (from the principal ingate) into the top of the prism; which latter should be formed broad and flat, and not taper upward, like a pyramid, lest, by cooling where it grows narrow, it might form a solid arch and oppose the pressure of the atmosphere. When it is fashioned as here directed, and made of a bulk equal to a third or fourth part of the mass of the mirror, or even a fifth or sixth part, when the mirrors are of large size there will ever be found in the top of the prism, after the metal is cast, a deep pit or cavity which contained the metal that had ran down into the mirror, after the outer shell of the mirror and sides of the prism had become solid and congealed; and the mirror itself will be found ferfect, without any sinking or cavity; which could only be formed by an injudicious disposition of the jet or appendage, permitting the metal in it to freeze sooner than the whole mass in the mirror, and thus stopping its descent into it. If several mirrors be cast together, in the same flask, there must be such a separate appendage made to each of them.

In this manner I have (without a failure in any) cast many mirrors of different sizes, and sometimes several of them together in one flask. But very small ones, such as the little mirrors for Gregorian telescopes, cannot be cast in this manner; for their masses being but small, they cool too quickly to receive any additional infusion of metal; and their outer edges, suddenly forming a solid incompressible arch, the central parts, in contracting towards it on every side, separate, and are rent asunder. And this has happened, even when I cast them in brass moulds made red hot: on which account I have been obliged to form them out of pieces of the metal, cast in long thin ingots or bass; which, by nicking them across with a file, could be easily broken into square pieces,

whose corners could be taken off, and rounded in the same manner.

I do not repeat the other precautions to be observed in this process, which have been already so well and sagaciously described by the Rev. Mr. Edwards; but the circumstances above mentioned, a prudent attention to which is in my opinion essentially necessary to the success of it, are not to be collected from any directions published on the subject that are known to me. And though particular artists may, by large experience, arrive at a sufficient knowledge in this matter for their own practice; yet, to render that knowledge general, and to contribute as far as I could to the improvement of this instrument in in any hands, being the design of this essay, I thought it necessary to state the above particulars fully; though I doubt not that these, as well as other matters of moment in the operation, are known to many who chuse not to make them public. Thus the great skill in the construction of the telescope, acquired by Mr. Short, seems not to have been transmitted to any successor.

16 *Nich. Jour.* 30.

I do not insert the rest of this valuable paper, because it relates merely to the method of *grinding* the specula: those who are interested in the construction of optic glasses, will do well to refer to it. I have made Edward's speculum metal, and with a small proportion of silver in it, I think it would be applicable to many other purposes. The polish and the colour are excellent.

In the report of Elias Boudinot, Esq. on the mint 1796, 1797, it is said that the beauty of gold coin is improved by making the alloy two thirds copper, and one third silver.

"*Copper precipitated by Tin.* An intelligent correspondent, Mr. Collard of Birmingham, the proprietor of

a chemical laboratory in that neighbourhood, in which many articles necessary to the arts and manufactures of this kingdom are prepared on a very large scale, has communicated to us a new fact well worthy of the attention of chemists.

" Contrary to the common tables of affinities, he finds that copper may be precipitated from its solution in the sulphuric acid by tin. All that is necessary to the success of the experiment is, that the solution be nearly at the boiling point, or actually boiling, when the tin is put into it. The tin made use of ought to be in filings or in leaf, or reduced to thin fragments by pouring it, when in fusion, into cold water.

" To the enlightened chemist we need not point out the experiments suggested by this new and curious fact, and the important results to which it may ultimately lead, If copper and tin, by a mere difference in the temperature of the solution, may be made mutually to precipitate each other, it is not impossible that the order of affinities with respect to other metals for the different acids may also be inverted by circumstances connected with temperature. Should any such results be obtained, they will be productive of incalculable advantages in many intricate cases of analysis. The different results obtained in apparently similar experiments, by equally accurate chemists, may perhaps have been owing in some cases to the existence of such a law as we now allude to."

24 *Philos. Mag.* 284.

Brazing. The soldering or joining two pieces of iron together by melting brass between the pieces to be joined. Clean well the edges of the iron. Take what is called spelter solder: or finely granulated brass, or brass dust, mix it up with pulverized glass of borax into a consistence by means of water. Smear with it the place to be brazed, and hold it over the flame of a charcoal fire,

without touching the coals, till the brass is melted: or fuse with a blow pipe.

I do not recollect at present, any further communication of consequence on the subject of *Copper*, except the following.

Glazed Copper and Iron Vessels.—A Mr. Hicklin some years ago obtained a patent for glazing iron and copper kitchen utensils; this can be done either with the common composition for Queen's ware (the common yellowish white pottery) or with the other receipts given by Mr. Hicklin, which I give as under: the queen's ware is composed of 3 parts by weight of good clay well ground, and washed, and one part of burnt flint in fine powder; it is glazed with a composition consisting of 100 parts white lead, 25 parts ground flint, and 5 parts ground flint glass, which contains about one fifth of lead.

Hicklin's compositions are these: 6 parts calcined flint, 2 parts white granite, 9 parts litharge, 6 parts borax, 1 part clay, 1 part nitre, 6 parts calx (oxyd) of tin, 1 part potash.

In this, the white granite, probably means the decomposed feldtspar of the granite, such as abounds near Philadelphia and Baltimore: some of the other fluxing ingredients might be omitted, as the potash for instance, but they are not very expensive.

Or, 8 parts calcined flint, 8 parts red lead, 6 parts borax, 5 parts calx of tin, 1 part nitre.

Or, 12 parts white granite, 8 parts borax, 10 parts white lead, 2 parts nitre, 1 part of white marble lime, 1 part clay, 2 parts pearl ash, 5 parts calx of tin.

Or, 4 parts calcined flint, 1 part white granite, 2 parts nitre, 8 parts borax, 1 part white marble calcined (that is, lime), half a part clay, 2 parts calx of tin.

(The calx of tin is made by calcining in with heat exposed to the air; by fusing it with nitre, or by precipi-

tating it from muriat of tin, or by calcining it by digestion with nitric acid. In London there are persons who deal in white enamel, for the use of clock and watch makers, and who make a trade of calcining their tin which is the chief part of the composition; the flux being borax and flint glass, and I believe a little white arsenic.

Either of these formulas, are to be well mixed and then fused. While in fusion they are to be poured out on a clean iron or copper plate, and when cold, ground to a powder, passed through a sieve, again levigated with water, to which mucilage is to be added to keep the powder suspended. With this paste the inside of the vessel is to be smeared: when dry to be again slightly smeared over: then exposed to a heat sufficient to melt the composition; the vessel thus coated must be cooled gradually.

I have used of these vessels with great satisfaction.

T. C.

STARCH.

On the making of Starch. By Mr. JAMES GRAHAM, *of Berwick-upon-Tweed.*

STARCH may be made from a variety of articles:—potatoes, in particular, will yield a considerable quantity; but the great labour attending grinding or grating them down has hitherto prevented any great quantity of starch being made from that vegetable. When the potatoes are grated down, they do not require to be laid in steep to ferment after the manner of flour, but must be immediately strained through a sieve; and if the potatoes are of a good quality, the starch will settle to the bottom almost instantly: indeed the operation of straining after the potatoes are grated down cannot be performed too quickly. The produce, however, even from the best, is far less than most people would imagine; the best potatoes I ever used, only produced 4 or 4½ stones of starch from 40 stones of potatoes.

Potatoe starch is not saleable in the shops, not having so long and firm a grain as starch from flour; but if properly made is preferable to all others for blue-makers, as it melts or dissolves so easily, and incorporates with the colour with far less trouble than any other substance whatever.

When starch is made from flour, the wheat is not ground so small as when intended for sale, but ground with a broader flag or bran, as the meal and starch are found to separate more readily from the bran. When laid in to steep, as much water must be used as to wet completely the whole meal; in three, four, or five days it will ferment, and in a few days more will settle, and all fermentation cease: after this, the stuff is fit to be what is called, washed out.

The common time allowed to steep is fourteen or twenty days: as much depends on the temperature of the weather, the exact time cannot be ascertained; but it is much better to lie a few days longer than to be washed out one day too soon. This operation is performed by the stuff being taken from the vats and put into a strong round basket, which is set across a tub below a pump: one or two men keep going round the basket stirring up the stuff with strong wooden shovels, called stirrers, while another keeps pumping water till all the meal is completely washed from the bran, which is emptied into some convenient place to feed hogs: this operation is continued till the vats are emptied of the whole stuff, at the same time that it is strained through the basket into the tub underneath. As fast as the tub fills, it is taken out and strained through hair sieves into what are sometimes called squares, by others, frames. It is then suffered to rest twenty-four hours, when the water is drawn off the frame by plugs fixed at different depths. A thin stuff is then found to float above the starch, which is taken off by a tray made of a particular form for that purpose: this is called slimes, and is put into a cistern to feed hogs, by being mixed with the bran or grains: fresh water is then pumped into the squares, and the whole is wrought up with the stirrers till it is completely incorporated with the water; it is then strained through a fine silk sieve, and suffered to rest and settle twenty-four hours, when the water is again drawn off, and some more slimes will be found floating, or at least in a loose and unsettled state, on the top of the starch; which being carefully removed, fresh water is again pumped on the starch, and the whole is again wrought up as before; when it is again put through the silk sieve.

It is now suffered to rest for some days,—say four or five,—till the starch is again settled in a very firm state at the bottom of the square. It is necessary to observe, if the starch is wanted to be what is commonly called Poland, that is, with the blue shade; during the last time of putting through the silk sieve, a certain quantity of the very best smalts must be mixed with the starch. If the smalts are very good, 2lb. per cwt. may do, and sometimes 3lb., according to the depth of blue wanted: if the best smalts are not used, however fine the colour may appear when in a damp state, it will entirely fly off in the stove, and leave the starch of a dingey hue.

When the starch is found to be completely settled, the water is again drawn off; and if any more slimes are still on the top they are taken off as before, and the starch is now fit for boxing. It is necessary to observe, that the slimes taken off after the starch has been put through the silk sieve are not put into the hog-wash, but are either mixed with some other operation, or again wrought up with water and strained through the silk sieve; when a considerable part of them will be tolerably good starch.

The boxes may be made of different sizes; but they are commonly about four feet long, six inches deep, and twelve inches broad, and are bored full of holes, so that any remaining water may drain from the starch. Thin canvass is cut in such length and breadth as to line all the inside of the box, the intention of which is to bring the starch clean from the box after the water is fully drained.

The boxing is performed by digging the starch out of the square with a spade or shovel, and filling the boxes. The length of time for the starch being in the boxes can only be ascertained by the starch coming to a hard solid body, which is sometimes sooner and sometimes longer. The starch is then taken from the boxes by turning them bottom uppermost on a table or dresser; it is then broken into pieces about four or five inches square, by laying a ruler or round piece of wood underneath the starch, giving the upper side a cut across with a knife; when a small press of the hand will break the starch into such pieces as are designed.

It is then set upon soft bricks, that is, bricks which have been only half-burned in the kiln: the intention of this is to suck the water out of the starch; which if not done before it is put into the stove, it is apt to dry into various hard substances called hamy,

which will not melt when it comes to be used; so that it will not answer for blue-makers, nor for the purpose of the laundry.

When sufficiently dried on the bricks it is put into the stove, (which is nearly the same as a sugar-baker's,) where it remains some time: the duration must depend on the judgment of the maker, and the degree of heat in the stove. It is then taken out and set on a table or dresser, when all the sides are carefully scraped or pared with a thin knife; after which, it is tied up in paper the same as we see it in the shops; when it is again returned into the stove, and continued with a regular heat night and day till completely dry: it requires some days, but the length of time can only be ascertained by an experienced maker.

It may be necessary to observe, that from the first laying in the meal to steep, till the last operation of taking from the stove to be weighed, the manufacture is constantly under the survey of one or more officers of excise.

19 *Philosophical Magazine, p.* 166.

MANURES.

A PLANT contains *water;* that is hydrogen and oxygen: *Carbon*, that is charcoal: *Hydrogen*, usually combined with the charcoal, and giving out light and flame when the vegetable is burnt, as carburetted hydrogen: *Vegetable acid*, that is carbon, hydrogen, and oxygen: *Potass*, whence derived or how formed I know not: *earths and salts* in small and accidental quantities, deposited as I apprehend from the fluids taken up by the roots: these are not found uniformly, either in kind or quantity, and they vary in both respects with the nature of the soil and of the manure. Thus, the calcareous earth found in potatoes, and the siliceous earth found in the scouring flag, in the straw of grain, in the joints of reeds and canes, &c. can hardly be considered as essential parts of vegetable substance, any more than the nitre in borage, in tobacco, &c. which, if the vegetable organization cannot decompose, must exist deposited in its proper form.

Hydrogen, oxygen, and carbon then, are the principal component parts of vegetables: even potash seems not essential to all vegetables, inasmuch as the resinous plants contain it in very small

proportions indeed. Thus the ashes of pine, are worthless in our families.

The roots of a plant, do not seem capable of taking up and conveying to the sap vessels, any solid substance. Hence, manures of pabulum can only consist of such substances as being composed of hydrogen, oxygen, and carbon, all three, or any two of them, are capable of watery solution, and also of being decomposed by the powers of vegetable organization.

Of these three principles, carbon is the first in importance, as forming so large a part of the solid substance of a plant. But the solution of carbon in water cannot be effected alone, and it seems to have remained as a desideratum in chemical agriculture, till the experiments of Arthur Young, Esq. of which I am about to give an account.

In the 43d volume of the Annals of Agriculture, p. 433, there is a paper by the editor, A. Young, Esq. on the effect of sixty-four mixtures of substances intended as manures, on plants of barley. The mixtures to be sure are not very scientifically combined, but there is no material objection that I see, to the general results of the experiments. They were made in 1803. The paper is long, I shall therefore extract only the result: premising, that No. 16 consisted of half an ounce of powdered charcoal, and half an ounce of powdered pearl ash, in three quarters of a pint of water, well shaken for six hours.

No. 31 was half an ounce cut straw steeped in putrid stable urine for three days.

No. 64 is nothing but nitre with excess of acid; being equal weights of pearl ash and aqua fortis, in double the weight of water.

His notion that the good effect of muriat of soda, common salt, is to be attributed to the soda alone, is manifestly owing to imperfect notions of chemistry, and physiology. The paper is closed by the following observations, which I present to the reader.

"*Observations.*—That the result may appear in a more simple manner, I shall throw the numbers into the order of merit, adding together the number of grains and the weight of the straw.

No. 16	Pearl ash and charcoal fluid - -	715
31	Straw steeped three days - -	473
19	Holkham loam - - -	320
64	Pearl ash and spirit of nitre - -	296
60	Soda - - - -	291

No. 41	Soot	289
32	Chalk and salt	269
35	Gypsum	244
61	Bay salt	212
22	Salt	196
27	Straw steeped 15 hours	193
21	Salt	188
25	Straw steeped 3 hours	188
17	Fleg loam	185
33	Chalk and salt	177
37	Do. gypsum and spirit of hartshorn	177
63	Magnesia	177
24	Salt	167
14	Pearl-ash	167
36	Chalk and gypsum	164
23	Salt	151
59	Nitre	148
15	Pearl-ash and charcoal dry	146
34	Chalk	145
35	Gypsum	144
28	Spirit of hartshorn	142
62	Iron filings	140
26	Dry straw	139
20	Salt	136
13	Charcoal	128
57	Bottle 5	123
44	Salt	105
39	Soot	96
2	Spirit of wine	95
29	Spirit of hartshorn	93
8	Bottle No. 2	92
43	Salt	92
40	Soot	88
6	Bottle No. 1	87
42	Gypsum	84
54	Chalk and hartshorn	82
47	Gypsum	79
52	Bottle No. 5	78
11	Ditto No. 4	78
4	Spirit of wine	77
55	Bottle No. 5	76
38	Chalk and spirit of wine	74

No. 30	Spirit of hartshorn	73
50	Spirit of wine	68
56	Charcoal and spirit of hartshorn	63
49	Spirit of wine	63
3	Spirit of wine	60
1	No manure	57
9	Bottle No. 2	55
7	Ditto No. 1	54
12	Bottle No. 1	48
5	Spirit of wine	46
10	Bottle No. 4	28
58	Ditto No. 5	28
45	Salt	26
53	Gypsum and bottle No. 3	25
48	Bottle No. 5	17
18	Poor sand	11

Remark I. If this experiment had ascertained no more than the solubility of charcoal in water by means of pearl-ash, the time employed would not have been lost. Ingenhouz says, it is totally insoluble in water. Mr. Davy however knows better—he observes, that hot soap-lees will dissolve *some;* and that potash and pearl-ash have *some effect* in rendering charcoal soluble in water. *(Lectures).* Darwin hints at it (240). Dr. Thompson, in his Chemistry, speaks of its probability. *It is not improbable.* Senebier, that pure alkalis dissolve *a small quantity; but not when combined with acids.* III. 155. In another passage *it is insoluble in water, and the alkalies alone have the power of dissolving some particles.* III. 57. From reading these and other passages, and from Mr. Kirwan declaring that to discover the means of rendering charcoal soluble in water, was the great desideratum respecting manures, I concluded that the result was at least very doubtful—but of such complete success, I had no comprehension. It appears that mixed in water, and applied in such a loam, the solution, effective as a manure, takes place; as the pearl-ash alone, and the charcoal alone, (though both good manures) have an effect far inferior.

II. That straw steeped in urine should act powerfully is not surprising; but I did not expect that dry straw would have had the effect of more than doubling the fertility of the soil. Many reflections relative to the application of dung in a fresh or rotten state,

will occur to the reader on this fact. The superiority of No. 30 to 31 in the turnips is remarkable, and shews, that however powerful urine is for one crop, its effect quickly goes off.

III. The result of the several applications of common salt is remarkable. Chalk and salt have an uncommon effect, and from the soda alone having so great a power, it seems evident that in the composition of muriat of soda, it is the soda to which we are to attribute the benefit. The various portions of salt tried (for the inquiry is particularly interesting), and their general result, do not seem to permit any doubt of its efficacy as a manure.

The largest quantity applied, having the effect in the turnips of counteracting a great drought, is remarkable.

IV. The nitrate of potash, whether in a state of solution or solid, has a great effect, but in the former case much superior to the latter.

V. In every application sulphat of lime is beneficial; the single exception of No. 53 is so complex, that it does not merit attention, especially as the quantity of spirit of wine was large.

VI. In the experiments I made many years ago, spirit of wine was almost uniformly mischievous or useless. I had reflected often on a result which was so contrary to all expectation, and concluded that I must have applied the substance in too large quantities. This year I lessened them considerably; and the result is much more favourable: but here one tea-spoonful is better than four; and half and quarter better than three. However, its being beneficial in five cases out of six, shews that it is an inquiry which merits further prosecution.

VII. Spirit of hartshorn appears to advantage, and as the three pots No. 28, 29, and 30, are in the succession of diminished quantities, it shews that the smallest applied might have been too great for the first crop.

But I forbear adding more remarks—here are too many, for this is more properly the readers' work, whose conclusions may be very different from mine."

I think this set of experiments may reasonably be pursued; and the effect of charcoal dissolved in alkali in various proportions as well with heat and without, be usefully compared both as to effect and economy. T. C.

BRICKS.

I HAVE already treated this subject in my last number: but considering it of great importance, as well as the making of mortar, which I shall treat of probably in my next, I have carefully read over Bergman's essay *de laterum coctione rite instituenda*, Op. vol. 4. p. 336, and the article Bricks in Rees's and in the Edinburgh (Brewster's) Encyclopædia. I shall therefore copy the latter article, adding some further observations of my own.

BRICK, a kind of facitious stone, made of argillaceous earth, formed in moulds, and baked in kilns, or dried in the sun.

This substance is now in very common use as a material for building; and its importance, in many cases, as a substitute for stone, is generally acknowledged. It is lighter than stone, and not so subject to attract damp and moisture; and from the quantities that are now made in Britain, its manufacture has become a considerable object of revenue to the state.

The art of brick making consists chiefly in the preparing and tempering of the clay, and in the burning of the bricks; and as the quality of the ware depends very much upon the right performance of these operations, we shall present our readers with a short sketch of the general process of this manufacture. The earth proper for making bricks is of a clayey loam, neither abounding too much in argillaceous matter, which causes it to shrink in the drying, nor in sand, which renders the ware heavy and brittle. As the earth, before it is wrought, is generally brittle and full of extraneous matter, it should be dug two or three years before it is used, that, by being exposed to the action of the atmosphere, it may be sufficiently mellowed and pulverised, and thus facilitate the operation of tempering. At any rate, it should always have one winter's frost; but the longer it lies exposed, and the more it is turned over and wrought with a spade, the better will be the bricks.

The tempering of the clay is performed by the treading of men or oxen, and in some places by means of a clay mill. If the operation be performed by treading, which is the common way, the earth is thrown into shallow pits, where it is wrought and incorporated together until it is formed into a homogeneous paste, which is facilitated by adding now and then small quantities of

water; but the less water that is used, the substance of the clay will be more tough and gluey, and consequently the bricks will be smoother and more solid. This operation is the most laborious part of the process; but it is of essential importance, and therefore ought to be done well; for it is to the negligence of the manufacturers in this respect, that we are to attribute the bad quality of our modern bricks, which are often light and spongy, and full of cracks. Whereas, if the clay be properly tempered, they are hard, ponderous, and durable; much stronger and better fitted for every kind of building, than those made in the common way. This will appear very evident from the following experiment of M. Gallon. Having taken a quantity of brick-earth, tempered in the usual way, he let it remain exposed to the air for seven hours, and then caused it to be moistened and beaten for the space of half an hour: the next morning the operation was repeated; and in the afternoon the clay was again beaten for fifteen minutes more; making the whole additional labour an hour and a quarter. The bricks made of this earth being dried in the air for thirteen days, and burned along with the rest without any particular precautions, were found to be not only heavier than common bricks, but also very different in strength; for on placing their centre on a sharp edge, and loading both the ends, M. Gallon found, that while it took a weight of 65lb. at each end to break them, other bricks were broken by the weight of only 35lb. The improvement in the quality of the article thus far exceeds the additional labour; and none would hesitate to give an additional price, since both the value and the comfort of our dwellings depend so much on the quality of the materials of which they are constructed.

The next part of the process is the moulding of the bricks. This is a very simple operation, and requires very little skill, unless it be to make the greatest number in the shortest time; and the day's labour of a handy workman, employed from five in the morning until eight at night, is calculated at about 5000. The clay is brought to the moulder's bench in lumps somewhat larger than will fit the mould. The moulder, having dipt his mould into dry sand, works the clay into it, and with a flat smooth stick strikes off the superfluous earth. The bricks are then carried to the hack, and there ranged with great regularity one above the other, a little diagonally, in order to give a free passage to the air. The hacks are usually made eight bricks high; and wide enough for two bricks to be placed edgewise across, with a passage between

the heads of each brick. In fine weather a few days are sufficient to make them dry enough to be shifted; which is done by turning them, and resetting them more open; and in six or eight days more they are ready for the fire.

Bricks in this country are generally baked either in a clamp or in a kiln. The latter is the more preferable method, as less waste arises, less fuel is consumed, and the bricks are sooner burnt. The kiln is usually 13 feet long, by 10½ feet wide, and about 12 feet in height. The walls are one foot two inches thick, carried up a little out of the perpendicular, inclining towards each other at the top. The bricks are placed on flat arches, having holes left in them resembling lattice-work; the kiln is then covered with pieces of tiles and bricks, and some wood put in, to dry them with a gentle fire. This continues two or three days before they are ready for burning, which is known by the smoke turning from a darkish colour to transparent. The mouth or mouths of the kiln are now dammed up with a *shinlog*, which is pieces of brick piled one upon another, and closed with wet brick earth, leaving above it just room sufficient to receive a faggot. The faggots are made of furze, heath, brake, fern, &c. and the kiln is supplied with these until its arches look white, and the fire appears at the top; upon which the fire is slackened for an hour and the kiln allowed gradually to cool. This heating and cooling is repeated until the bricks are thoroughly burnt, which is generally done in 48 hours. One of these kilns will hold about 20,000 bricks.

Clamps are also in common use. They are made of the bricks themselves, and generally of an oblong form. The foundation is laid with *place* bricks or the driest of those just made, and then the bricks to be burnt are built up, tier upon tier, as high as the clamp is meant to be, with two or three inches of *breeze* or cinders strewed between each layer of bricks, and the whole covered with a thick strata of breeze. The fire-place is perpendicular about three feet high, and generally placed at the west end; and the flues are formed by gathering or arching the bricks over, so as to leave a space between each of nearly a brick wide. The flues run straight through the clamp, and are filled with wood, coals, and breeze, pressed closely together. If the bricks are to be burnt off quickly, which may be done in 20 or 30 days, according as the weather may suit, the flues should be only at about six feet distance; but if there be no immediate hurry, they may be placed nine feet asunder, and the clamp left to burn off slowly. Coke has been recommended as a more suitable fuel than either coal or wood

for this manufacture, both with regard to the expence, and the proper burning of the bricks; for if this substance be applied, the flues or empty places of the pile, as well as the strata of the fuel, may be considerably smaller; which, since the interference of the legislature with regard to the measurement of clamps, is no small consideration; and as the heat produced by coke is more uniform and more intense than what is produced by the other materials, the charge of bricks has a better chance of being burnt perfectly throughout, so that the whole saving may be calculated at least at 32 per cent.

Mr. Goldham observes, that bricks will have double the strength if, after one burning, they be steeped in water and burned afresh. "The excellency of bricks," says Mr. Malcolm, in his *Compendium of Modern Husbandry*, "consists chiefly in the first and last operations—in the tempering of the clay, and in the burning of the bricks; and as every man who has occasion to use bricks, whether on his own estate, or on that of his landlord, cannot but be sensible of the great value of a perfectly dry house; and, as it is impossible a house can be dry if bricks are used which are insufficiently burnt, he will do well to consider whether it will be more advantageous to him in the end, to make use of the very best hard sound bricks, be the colour of them what they may, and be the cost of them what they will. Such bricks are easily known by their sound, and by their striking fire with steel." For a more minute account of the various processes of brick-making, we must refer our readears to that author, from whom much of the preceding information has been extracted.

Bricks are made in various forms; but those which are made for sale, and are in common use for building, are required, by act of parliament, to be not less than $8\frac{1}{2}$ inches long, $2\frac{1}{2}$ thick, and 4 inches wide. There are also square bricks, for pavement or facing walls; and cutting bricks, which are used for arches over doors and windows, being rubbed to a centre, and guaged to a height. Various improvements, however, have of late been made in the moulding of bricks; and as the use of this article is daily becoming more prevalent, they are now formed so as to suit almost every purpose in building. Among these improvements, the patent bricks of Mr. Cartwright deserve particular attention. These bricks are formed with a groove down the middle, a little more than half the width of the side of the brick, leaving two shoulders, each of which will be nearly equal to one half of the groove. When these bricks are laid in courses, the shoulders of

the first course fit into the grooves of the second, and the shoulders of the second fall into the grooves of the first, thus forming an indented line of nearly equal divisions. The grooves, however, ought to be somewhat wider than the two adjoining shoulders, to allow for mortar, &c. The construction of these bricks is perfectly simple; but the principle will be preserved, in whatever form of indenture they may be made to lock into, or cramp each other. Brick walls, constructed upon this principle, require no bond timber; one universal bond connecting the whole building, which can neither crack nor bulge out without breaking through the bricks themselves. This invention is also particularly useful in the construction of arches; and when employed for this purpose, the shoulders of the bricks and the sides of the grooves should be radii of the circle, of which the intended arch is a segment. It is, however, recommended, that if the arch be particularly flat, or applied in situations which do not admit of end walls, to have the shoulders dove-tailed, to prevent the arch cracking across, or giving way edgewise. In forming an arch, the bricks must be coursed across the centre, and a grooved side of the bricks must face the workmen. The bricks may be either laid in mortar, or dry, and the interstices afterwards filled up by pouring in lime-putty,* Paris plaster, or any other convenient material. The obvious advantages of arches constructed upon this principle, are, that the same centre, which, whatever be the breadth of the arch, may be in no case many feet wide, may be regularly shifted as the work proceeds; and as they have no lateral pressure, they require no abutments to prevent their expanding at the foot, nor any weight upon the crown to prevent their springing up. They may be laid upon a common perpendicular wall, and if used in the construction of common buildings, they will not only preclude the necessity, and save the expence of timber, but will also afford an absolute security against the possibility of fire.

A new invention in the formation of bricks, by M. Legressier, has lately been announced in the *Archives des Decouvertes et des Inventions Nouvelles, pendant l'annee* 1809. The principle, however, is merely that of Mr. Cartwright's, followed out to a greater extent than has perhaps ever been done in this country. M. Legressier proposes, that the bricks should be formed in seven different moulds, according as they are to be placed in the middle or on the exterior of the walls; in the bottom or on the top; in the arches or in the corners: and by the proper disposition of these bricks in the building, every pressure, either longitudinally

* Grouting.

or laterally, is resisted, in proportion to the strength of the indentures by which they are locked together.

Besides the place bricks and grey and red stocks, which are used in common building, there are marle facing bricks, cutting bricks, fire bricks, and floating bricks. The first of these are of a fine yellow colour, hard and well burnt; they are made in the neighbourhood of London, and are used in the outside of buildings. The cutting bricks are made of the finest kind of marle; and, as we have already observed, are employed in the construction of arches over windows and doors. Fire bricks, sometimes called Windsor bricks, because an excellent kind of them are made at Hedgesley, a village near Windsor. They contain a large proportion of sand, and will stand the utmost fury of fire, and are consequently used for coating furnaces, and lining the ovens of glass-houses. Clay for fire bricks is got at most great collieries, but particularly at Stourbridge, which produces the best clay for this purpose in England. Floating bricks are a very ancient invention: they are so light as to swim in water; and Pliny tells us, that they were made at Marseilles, at Colento in Spain, and at Pitane in Asia. This invention, however, was completely lost, until M. Fabbroni published a discovery of a method to imitate the floating bricks of the ancients. According to Posidonius, these bricks were made of a kind of argillaceous earth, which was employed to clean silver plate. But as it could not be our tripoli, which is too heavy to float in water, M. Fabbroni tried several experiments with mineral agaric, guhr, lac-lunæ, and fossil meal, which last was found to be the very substance of which he was in search. This earth is abundant in Tuscany, and is found near Casteldelpiano, in the territories of Sienna. According to the analysis of M. Fabbroni, it consists of 55 parts of siliceous earth, 15 of magnesia, 14 of water, 12 of argil, 3 of lime, and one of iron. It exhales an argillaceous odour, and when sprinkled with water throws out a light whitish smoke. It is infusible in the fire, and though it loses about an eighth part of its weight, its bulk is scarcely diminished. Bricks composed of this substance, either baked or unbaked, float in water; and a twentieth part of argil may be added to their composition without taking away their property of swimming. These bricks resist water, unite perfectly with lime, are subject to no alteration from heat or cold, and the baked differ from the unbaked only in the sonorous quality which they have acquired from the fire. Their strength is little inferior to that of common bricks, but much greater in proportion to their weight; for M. Fabbroni found, that

a floating brick, measuring 7 inches in length, $4\frac{1}{2}$ in breadth, and one inch eight lines in thickness, weighed only $14\frac{1}{4}$ ounces; whereas, a common brick weighed 5 pounds $6\frac{3}{4}$ ounces. The use of these bricks may be very important in the construction of powder magazines and reverberating furnaces; as they are such bad conductors of heat, that one end may be made red hot, while the other is held in the hand. They may also be employed for buildings that require to be light; such as cooking places in ships, and floating batteries, the parapets of which would be proof against red hot bullets. The turrets which were raised on the ships of the ancients, says M. Fabbroni, were perhaps formed of these bricks; and perhaps they were employed in the celebrated ship, sent by Hiero to Ptolemy, which carried so many buildings, consisting of porticoes, baths, halls, &c. arranged in mosaic, and ornamented with agates and jasper.

Bricks appear to be of the highest antiquity; and, as we learn from sacred history, the making of them was one of the operations to which the children of Israel were subjected during their servitude in Egypt. The bricks of the ancients, however, so far differed from ours, that they were mixed with chopped straw in order to bind the clay together, and instead of being burned were commonly dried in the sun. Vitruvius recommended, that they should be exposed in the air for two years before they were used, as they could not be sufficiently dry in less time; and by the laws of Utica, no bricks were allowed to be used, unless they had lain to dry for five years. From Dr. Pocock's description of a pyramid in Egypt, constructed of unburnt bricks, it appears that the Egyptian bricks were nearly of the same shape as our common bricks, but rather larger. Some of those he measured were $13\frac{1}{2}$ inches long, $6\frac{1}{2}$ broad, and 4 inches thick; and others 15 inches long, 7 broad, and $4\frac{3}{4}$ thick. The bricks used by the Romans were in general square; and M. Quatremere de Quincy observes, that in his researches among the antique buildings of Rome, he found them of three different sizes. The least were $7\frac{1}{2}$ inches square, and $\frac{1}{2}$ thick; others $16\frac{1}{2}$ inches square, and from 18 to 20 lines in thickness; and the larger ones 22 inches square, by 21 or 22 lines thick. Among the celebrated buildings of antiquity, constructed of brick, were the tower of Babel, and the famous walls of Babylon, reckoned by the Greeks among the wonders of the world; the walls of Athens, the house of Crœsus at Sardis, and the walls of the tomb of Mausolus. The paintings, which were brought from Lacedæmon to Rome, to ornament the Comitium in the

edileship of Varro and Murena, were cut from walls of brick; and the Temple of Peace, the Pantheon, and all the Thermæ, were composed of this material. The Babylonian bricks, which are in the possession of the East India company, and upon which Dr. Hayes has lately favoured the public with a dissertation, are inscribed with various figures and characters, and are supposed by some to be a part of that brick work, upon which Pliny tells us that the Babylonians wrote the observations which they made of the stars for seven hundred and twenty years.

To the above article I would add the following remarks:

1st. The floating bricks therein mentiond, I understand are made by an admixture of pumice dust with the clay.

2d. It is worth while to try clay intended to be used as brick earth. If it contain coarse sand, it ought by all means to be washed, that the small stones may subside: indeed washing and grinding clay, as the common potters do, would be a great improvement on the quality of brick earth.

3d. It should be tried if it contain small particles of limestone; for if it do, the fire will blister and crack the brick by driving out the carbonic acid of the limestone. This may be done by boiling an ounce or two of the clay taken from separate parts of the bed, with a mixture of half water and half spirits of salt, or muriatic acid, which in an hour's time will dissolve the limestone, and this can be separated or thrown down by saturating the acid with pearl ash. The sand can be separated from the clay, by repeated ablution and subsidence.

4thly. Where bricks approaching to porcelain are wanted for particular purposes, the clay should be freed from coarse particles by washing, and mixed with some fine sand and lime. Clay 1 part, lime 1 part, and sand two or three parts will make a mixture that will enter into half fusion in a brick kiln.

5thly. No more sand should be added to brick earth in a common way, than is sufficient to prevent too great a contraction of the clay by the fire.

6thly. Too sudden a fire warps the bricks by the violent extrication of the steam: and too violent a fire is apt to make them run together. Where the expence is not an object, a brick twice burnt, is excellent. I have already mentioned in this work, what I wish potters would notice, that I have never seen the coarest common pottery that by a second gradual and continued burning,

might not be converted into *stone ware*. I have done this repeatedly.

7thly. If the bricks are required to be glazed externally, it can be best done by throwing a bushel of common salt into a kiln of bricks while at their greatest heat, and stopping the top of the kiln.

8thly. The best bricks are made of well burnt clay containing but a small proportion of fine sand. Turning up the earth in the autumn, to expose it to the winter's frost—well working it in the spring before it is moulded—gradual and continued burning in the kiln or clamp, are all of them absolutely essential to a good brick: few of these requisites are usually well performed.

The legislature in England has often interfered in the manufacture of bricks; and considering how much the health of the inhabitants of large towns, depends upon the goodness of bricks, especially in such a climate as England, I am not much inclined to find fault with this interference. By 12 Geo. 1. ch. 35. earth or clay designed for bricks made for sale, shall be dug and turned once at least between the first day of November and the first of February; and not made into bricks till after the first day of March: nor shall any brick be made for sale, but between the first day of March and the 29th of September. But the 10 Geo. 3. ch. 49. earth may be dug at any time of the year, provided such earth be turned once before it be made into brick. By stat. 3. Geo. 2. ch. 22. not more than 720 bushel of sea coal ashes screened through a half-inch screen, shall be mixed with the earth of 100,000 bricks. By 17 Geo. 3. ch. 42. all bricks made for sale shall, when burned, be not less than $8\frac{1}{2}$ inches long, $2\frac{1}{2}$ inches thick and 4 inches wide.

From the want of breeze, or the small cinders of sea coal ashes, more fuel and longer time, are required to burn bricks in this country than in England. The clamps near Philadelphia usually contain about 50,000 bushels; 40 by 40, and 32 high: half a cord of wood is allowed to 1000 bricks: the burning of a clamp takes about a week. Near London, the clamps usually contain 100,000, and the burning last about a fortnight.

9thly. I weighed two bricks that had long been kept in a room in the college here and were perfectly dry. They weighed $10\frac{1}{2}$lb. Immersed in water for an hour they weighed 11lb.

T. C.

OHIO FALLS.

The following method of improving the Ohio Falls, is so applicable to similar falls, that I requested it of Mr. Dowers, the proposer. (See the plate.)

AAAA represents the Ohio river at the falls.

BB a part of the Indian Shute, 60 feet wide, and walled three feet high.

CCCC tributary dams, which turn their waters into the shute at an angle in opposition to the current. They are formed of stone and collect their water from the various separate or waste streams that pass down the falls on each side.

DDDD are openings in the side wall of the shute to receive the water from the tributary dams. They oblige the water to enter it at an angle in opposition to the current.

EFGH are ring bolts fixed at the bottom of the shute to fasten haussers to—to assist boats to ascend.

HH the lowest point of the tributary dams, raised about six inches higher than the openings D, which turn their waters into the shute.

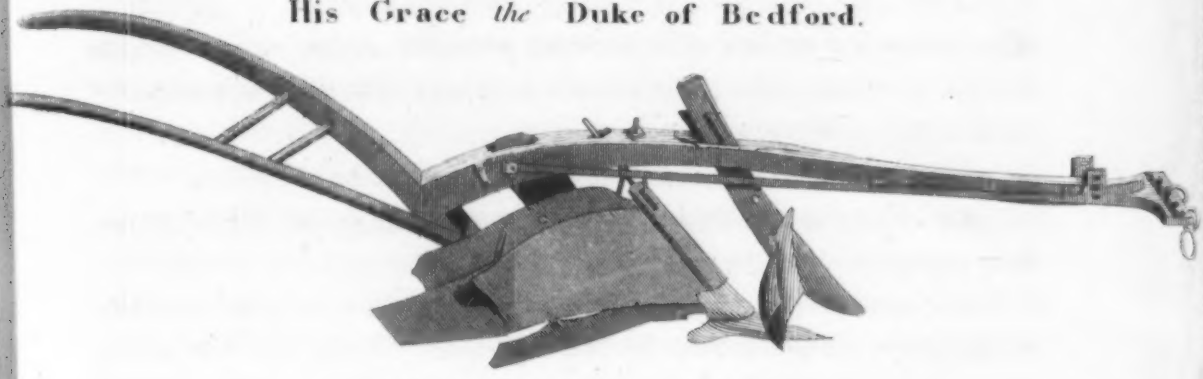
EXPLANATION.

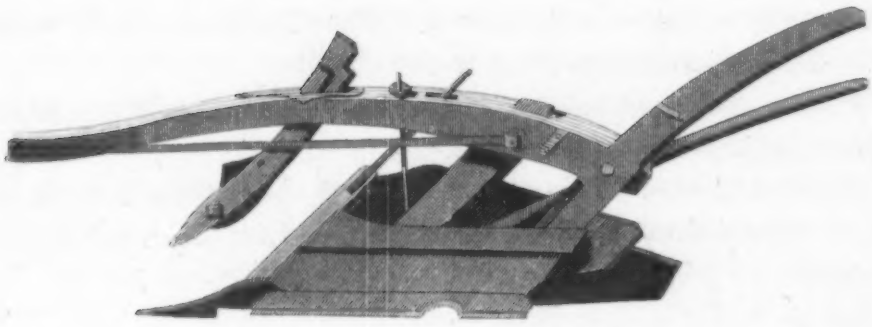
The above explanation relates to a plan for improving the passage of the falls of the Ohio without the aid of a canal and locks, which would be extremely expensive and the benefit at least doubtful. The plan proposed, it is believed, will answer the object as effectually and at a very small expence, comparatively speaking.

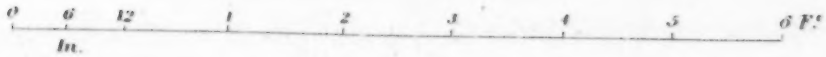
This plan supposes the improvement of the Indian shute, although it may perhaps be adviseable to make an entire new cut from the head to the foot of the falls, but this will depend on the judgment of the engineer. But whether the shute is used as a new channel, the principle and mode of arrangement, is the same. The channel, whether a new shute or the old, should be a regular inclined plane from the head to the foot of the falls; and the stone which is dug out, should be used to line the sides, to keep the water within it. A wall three feet higher than the bottom of the channel is amply sufficient. In order to understand the use of the lateral dams, let us suppose such a channel finished from the top throughout, and the water entering the upper end three feet deep and sixty feet broad, experience and reflection will

Mr. Duckets Skim Coulter Plough.

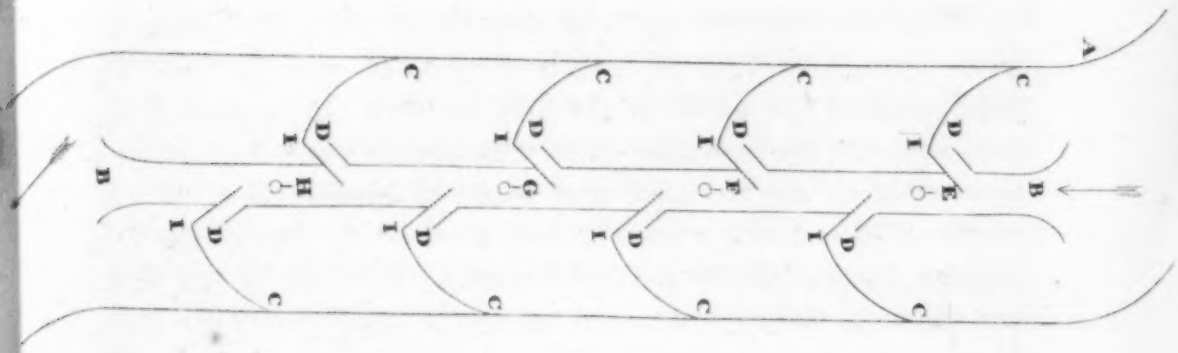
which gained the **Premium** *given by*
His Grace the Duke of Bedford.







Method of navigating the rapids of a River by Mr. Dowers.



C. TIBBOUT SC.

shew us that the descending water will not long preserve the depth of three feet, but will descend so rapidly as in a little time and before it reaches the bottom, be reduced to the depth of a few inches; this consequence uniformly attends water which passes over an inclined plane without obstruction. The rapidity, therefore, and want of depth, would make it of little use. To obviate this in a fall like the Ohio, which passes such a quantity of water, is easy. For having occasion but for a part of it in the first instance, the residue is suffered to move on, and is drawn in from time to time as you have need of it. If it was all compelled to enter the sluice at one time, it would create a fall at the upper end, besides overflowing your shute or channel. These lateral or tributary dams are therefore introduced, in the first place, to check the rapid descent of the water, and to keep up an adequate supply: the first it accomplishes by entering the channel at an angle in opposition to the current; the other by the quantity of water which it adds to it. At what distance those lateral dams might admit of being separated, and yet keep up the requisite supply, must depend on several considerations; but, it is evident, that they cannot be too close together, because the lower end of the dam at ‡ is but little higher than the wall of the shute, and discharges its water over, it if the shute is full, and by that means supplies the dam next below it, if it should require it, which also acts in like manner in its turn. These dams, however, are formed with but little trouble, nature having in all such falls, in a great measure, prepared them to your hand in the various curves and indenting of the rocks; nor is it at all necessary that they should be made with the regularity of the drawing—all that is necessary being to compel it to enter your channel at certain distances by a rough but substantial obstruction at any convenient point. And so easy is this done, that I have seen in the Susquehanna a counter current of more than a quarter of a mile, formed by a dam of loose round stones; the current running directly opposite to the natural course of the stream and almost as rapidly. These counter currents of the tributary dams will so check the velocity of the current in the shute that I make not the least doubt, that if it should be executed on this plan, of loaded boats being able to ascend with perfect ease.

With the aid of a small steam boat, which should avail itself of the ring bolts placed at certain distances along the shute, and, after joining them, draw after it successive a loaded boat. I should make no doubt of its ascending the falls with 100 tons.

BLEACHING: WITH A PLATE.

The plate to which this refers was sent to me some time ago, but not meaning to take up the subject of bleaching yet, I omitted it. However, as it is entitled to insertion, and I am obliged to the correspondent who sent it, I insert it now and shall refer to it hereafter.

AA The machinery to agitate the lime-water within the cask in which it turns round. BB The Still holding the materials.—1, 2, 3, 4, 5, 6, 7 places made air tight with water, to prevent the escape of the gas.

The following paper (which confers equal honour on king George III. and Arthur Young, and the plate that accompanies it,) will give my readers an idea of a genuine, thorough bred Merino Ram.

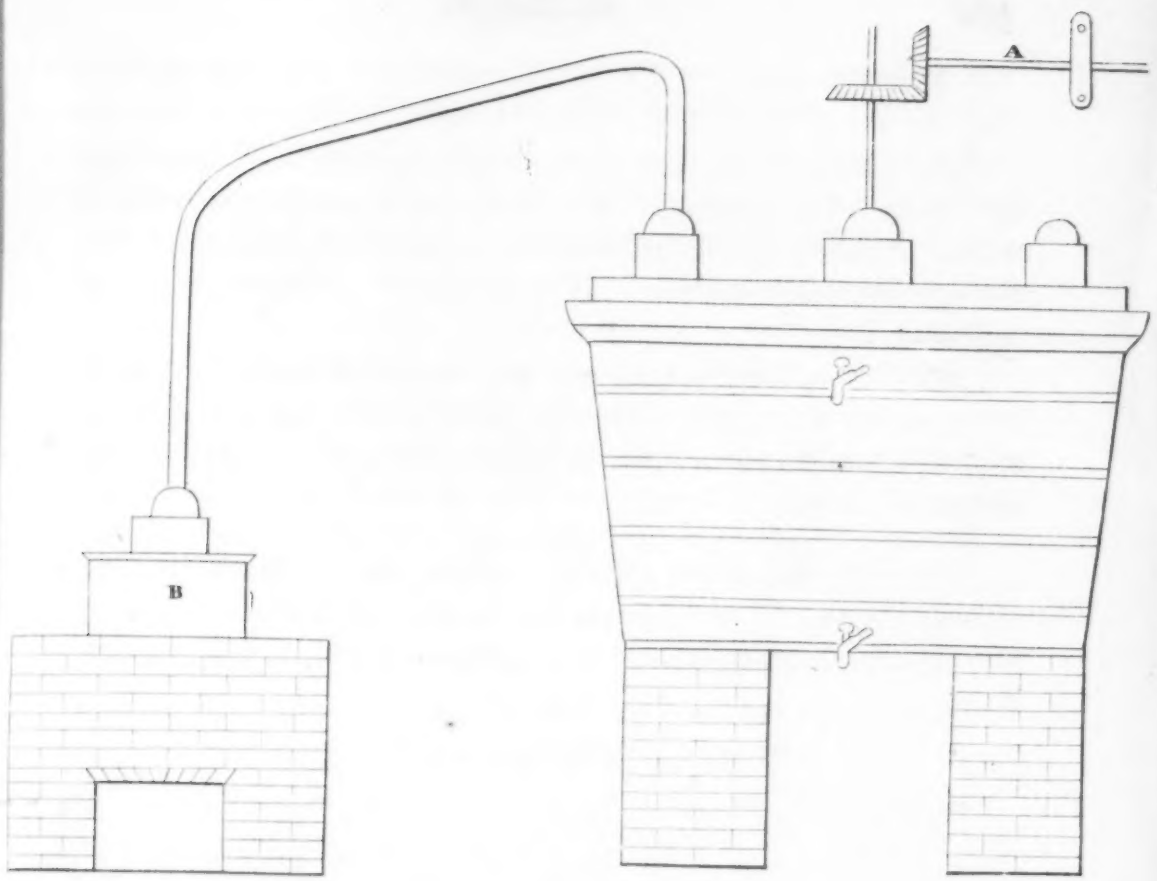
DON. A MERINO RAM, &c.

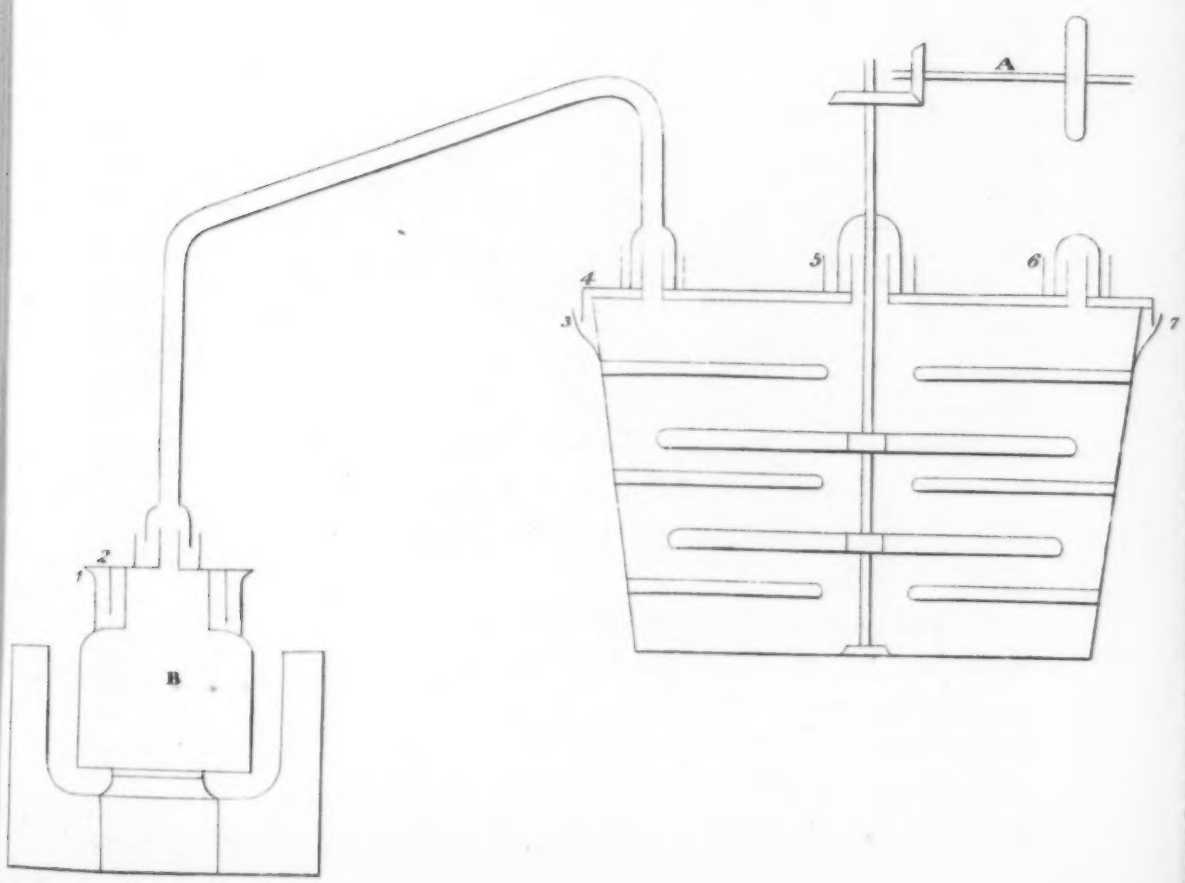
How many millions of men are there that would smile, if I were to mention the sovereign of a great empire giving a ram to a farmer, as an event that merited the attention of mankind: the world is full of those who consider military glory as the proper object of the ambition of monarchs; who measure regal merit by the millions that are slaughtered; by the public robbery and plunder, that are dignified by the titles of victory and conquest, and who look down on every exertion of peace and tranquillity, as unbecoming those who aim at the epithet *great*, and unworthy the aim of men that are born the masters of the globe.

My ideas are cast in a very different mould; and I believe the period is advancing, with accelerated pace, that shall exhibit characters in a light totally new; that shall rather brand than exalt the virtues hitherto admired; that shall place in the full blaze of meridian lustre, actions lost on the mass of mankind; that shall pay more homage to the memory of a prince that gave a ram to a farmer, than for wielding the sceptre—obeyed alike on the Ganges and the Thames.

I shall presume to offer but one other general observation:—when we see HIS MAJESTY practising husbandry, with that warmth that marks a favourite pursuit;—and taking such steps to diffuse a foreign breed of sheep, well calculated to improve those of his kingdoms;—when we see the royal pursuits take such a direction, we may safely conclude, that the public measures which,

BLEACHING.





in certain instances, have been so hostile to the agriculture of this country, have nothing in common with the opinions of our gracious sovereign: such measures are the work of men, who never felt for husbandry; who never practised; who never loved it:—it is not such men that give rams to farmers.

Measure of the Royal Ram.

Girt, - - - -	42 inches
—— at chine, - - -	36
—— of neck, - - -	20
—— of leg, - - -	4½
Thickness, - - -	11
—— at chine, - -	9
Length of carcass, - -	23
—— of neck, - -	7
Breadth of loin, - - -	6
Weight, - - - -	91 lb.

The thickness, *hardness*, and closeness of his coat, are singular; the colour to the eye very dark, dirty, and even blackish, arising from the superior degree of closeness; but when opened, for examining the wool, the extreme beauty of the staple is at once apparent. The fibre fine; twisted; full of that yellowish waxy grease, that distinguishes the Spanish fleeces; the skin oily to an extraordinary degree.

In regard to the thriving quality of this breed, it is a point of such importance, that I was anxious to ascertain it: of the wool, none could have any doubt; but from certain points, which predominate in Spanish sheep, this was certainly a question; I had it not in my power to make a trial absolutely complete, but I formed a comparison, the result of which follows:—I tied him up in stalls during a part of the winter, and the rest of it he was in the field, fed exactly (during the whole) as other rams that were compared with him. In stalls, he beat the Norfolk breed.

No. 1.	Dec. 31, Don Weighed - - -	84 lb.
2.	A ram ½ South Down, ¼ Norfolk, ¼ Bakewell, - -	141
3.	A South Down, from Mr. Ellman	136

These were fed abroad together till March 20th, when they weighed

No.	lb.	Gain.
1,	100	16
2,	148	7
3,	144	8

This was a superiority, which, I confess, I did not dream of.—The comparison is not exact, because the ages are not the same. No. 1, has eight broad teeth; No. 2, has six; and No. 3, has only four: but it seems to imply, that this ram is of a thriving race.

Another comparison of ram hoggets, proved favourable to the Spanish blood.

No.	Jan. 14.	Jan. 31.	Mar. 20.	G.
	lb.	lb.	lb.	
1, Half South Down, ¼ Bakewell, and ¼ Norfolk, -	97	94	82	0
2, Ditto, - - -	99	102	100	1
3, ½ South Down, ¼ Spanish, ¼ Reyland, - - -	99	104	108	9
4, Ditto, a late lamb, - -	37	50	48	11
5, Seven whole bred South Down; average weight, -	80	81	94	14

It should seem, from this, and various other trials, that so small an addition as one-fourth of Norfolk blood does a marked and essential mischief. Of these, No. 4 much exceeds the rest, a sheep of 37 lb. gaining 11 lb. is in the proportion of 23 lb. gain by one of 80 lb. instead of which it is only 14 lb.

Speaking generally, I believe the Spanish blood will be found to have a good disposition to fatten, if not in the same class as some of our long woolled breeds, at least much superior to some of our fine woolled ones.

I put him to forty of my finest woolled South Down ewes, and therefore may expect to breed some rams well adapted to propagating fine wool, and some ewes, which, covered two years hence by Don, will give me a yet nearer approximation. A. Y.

[17 *Ann. Agr.* 529—533.

HYDROSTATIC ENGINE.

THIS invention, for which Messrs. Long and Hauto, have recently taken out letters patent, under the authority of the U. States, and which they have secured in England, Scotland and Ireland; is offered to the public, as a valuable and cheap substitute for the common overshot wheel, in all situations, where there is a scarcity of water, with a fall of 25 feet and upwards.

DON,

A Merino Ram given by his Majesty, to Arthur Young Esq. the Editor of the Annals of Agriculture, 1792.

Fig. 4. An internal view of one side of the groove-box, in which the sliders are so disposed, as to keep the sides of the rack alternately in gear, with the rack-wheel. The sliders represented by shades in this figure, are to consist of iron, and to be made fast to the sides of the groove-box, by means of screw-bolts. The uppermost is so constructed, as to permit the regulator in the end of the rack to pass around it.

Fig. 5. A view of a part of the dog, and its friction wheel, upon which the weight of the rack is supported.

Fig. 6. A view of one side of the frame at the back part of the machine, showing one of the grooves, in which that part of the carriage moves, to which the sweep is attached.

Fig. 7. A side view of the valve, with the winch by which it is turned.

Fig. 8. The pullies in the top of the dog, together with a part of the valve-rod.

Fig. 9. The carrier or regulator, to be attached to the lower part of the rack, at its outermost end. The ears upon the sides are fitted to the grooves of the groove-box, so that they pass entirely round the uppermost slider.

Figs. 10 and 11. The parts of the machine represented by these figures, are intended for a substitute for the groove-box and sliders. A model has been constructed on this plan, and it is found to answer the purpose far better, than the original plan. The greater part of the friction of the rack is completely done away by it. These figures represent different views of a catch-frame, with friction-wheels, bolts, and bolt-mortices. The friction wheels are placed so far asunder, as to admit the rack to pass freely between them. The frame at every change of the rack, rises and falls with it. It is confined in such a manner by the bolts, that it keeps the sides of the rack alternately in gear, with the rack-wheel. The bolts slip alternately into the mortices, by means of small weights, acting upon angular leavers or dogs; and are drawn out of them again, by the ends of the rack striking against pins or knobs, in the bolts.

According to Fig. 1, as the water acts alternately upon the pistons, it follows, that a reciprocated rectilinear motion is produced. This motion is accompanied by a power equal to the weight of a column of water, whose base is the area of one of the pistons, and whose height is equal to the whole perpendicular fall of the water. For instance let the whole perpendicular fall be 33 feet; the weight

HYDROSTATIC ENGINE.

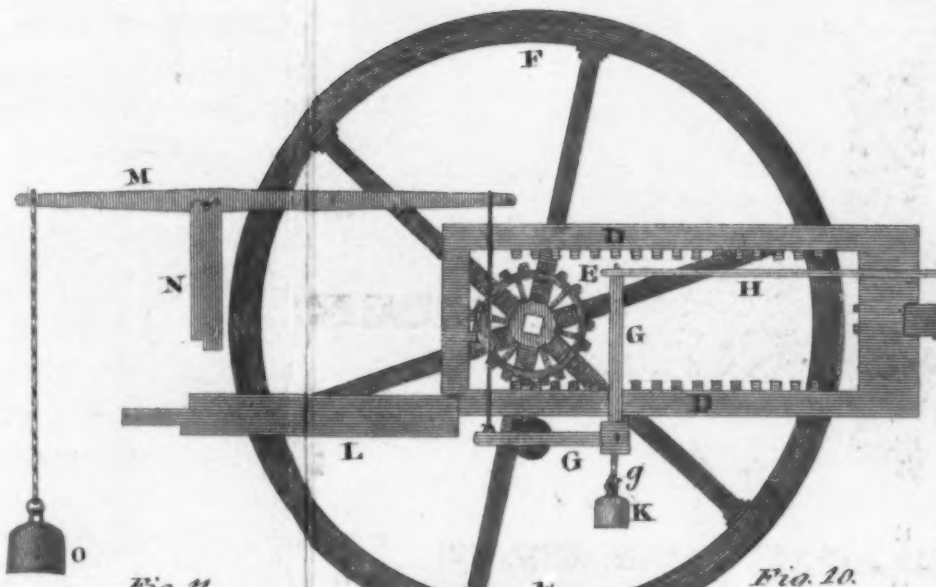


Fig. 11.

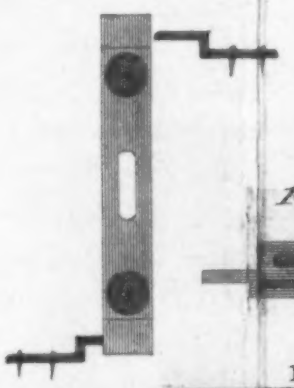


Fig. 10.

Fig. 5.

Fig. 4.

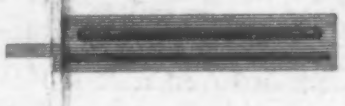


Fig. 2.

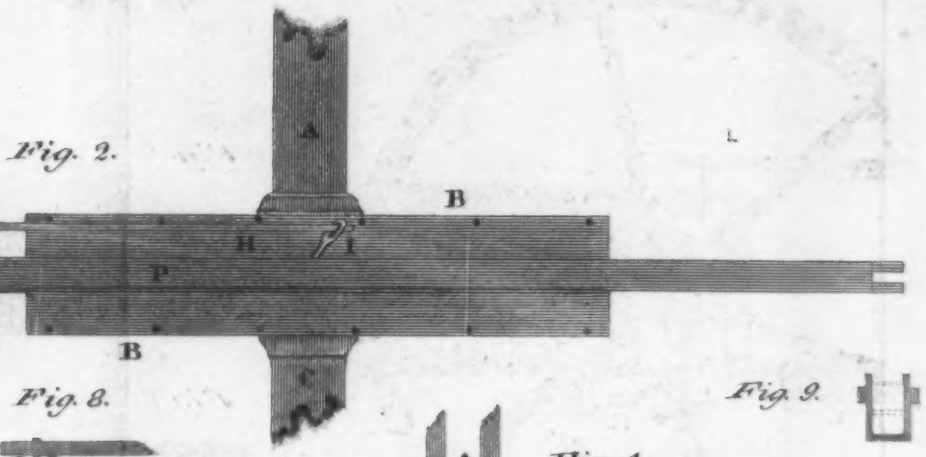


Fig. 8.

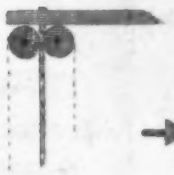


Fig. 9.

Fig. 1.

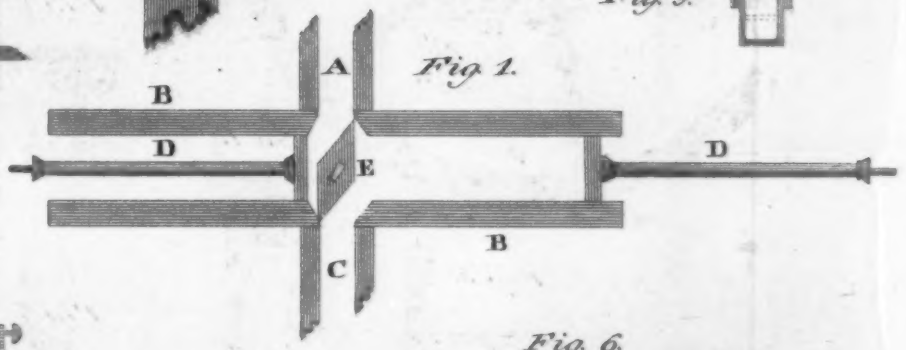
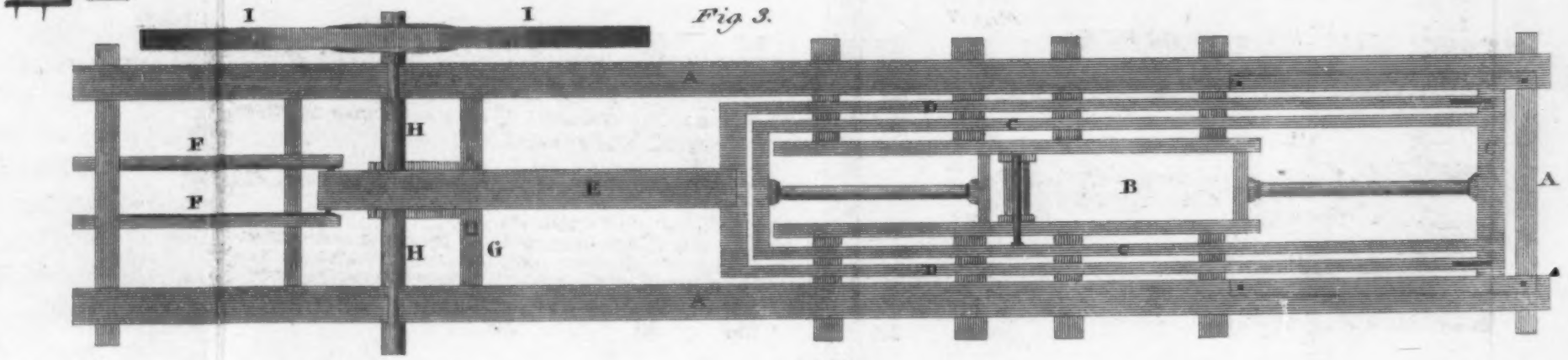


Fig. 7.

Fig. 6.

Fig. 3.



Engraved by H.Anderson, from an original drawing by W.Lehman.

or power will be 15 pounds upon every square inch of the piston. When the fall is sixty-six feet, the power is 30 pounds upon the square inch, and a fall of 132 feet will give a power of 60 pounds, upon every square inch of the piston, and so on. In order to apply the power thus acquired to machinery, it is necessary that a rotatory movement should be produced. The manner in which this is effected is shewn by Fig. 2; by which it appears that the rectilinear movement bears the same relation to the rotatory, that a line of tangent does to its circle; and this indeed is the only direction, in which a power acting in a right line, can produce a rotatory movement, without a very considerable loss.

It may be objected that the unavoidable friction to which the engine is liable, is sufficient to counterbalance all the advantages it might otherwise have, over the wheel, but an undeniable fact, which we will here introduce, will place this point beyond all controversy. An engine has been erected, at Mr. Bayly's brewery in Germantown, for the purpose of grinding malt. It is constructed on the original plan, viz. with sliders to regulate the movements of the rack. It is situated on a small stream of water, rising out of the ground, a few rods above the dam. The fall from the surface of the water in the dam, to the bottom of the machine, is equal to 25 feet perpendicular height. With this fall, grinding at the rate of 20 bushels per hour, the engine expends 100 gallons of water per minute. A grist-mill having an equal fall of water, and grinding at the rate of $3\frac{1}{2}$ bushels of wheat per hour, requires about 400 gallons of water per minute, to turn it.

Farther information on the subject and licenses may be obtained, by applying to the patentees in Germantown, near Philadelphia.

Mr. Hauto's Hydrostatic Engine. I observe there has been a kind of newspaper controversy between the proprietors of this machine, and Mr. Perkins, in which the latter insists that the water is not so advantageously applied by Messrs. Long and Hauto, as if it fell on a common water wheel. I will not pretend to say but that the water power might so be managed with a water wheel perfectly constructed, as to do equal work, with the machine contrived by Messrs. Long and Hauto; but it seems to me, that their machinery could be placed in situations where a water wheel could not be employed—that in many cases it would be cheaper than a water wheel—and in all cases more efficacious where the stream of water from the top to the bottom of the fall was not preserved in uniform continuity, which in water wheels, is not, as I think, always

easy to be done. But I am not a good machinist, and have no pretensions to decide. Of this I am persuaded, that if a poor man in a cellar in Front street, could rent a stream from one of the hydrants sufficient to turn fifty spindles, or a single loom on Mr. Siddal's construction, he would enable one of his children to earn more wages than he could himself in any usual way of manual labour.

It is true, no fall is gained from the Schuylkill to the Delaware, but there are always machines that do actually raise the water for the purpose of renting it out in portions. And every inhabitant of Philadelphia, feels that such an establishment is a great public convenience. A man might afford to pay a high rent for the hundredth or five-hundredth part of the power of a twenty-horse engine, who could not afford to erect such an engine himself. I state this, merely as one of the cases that may be put, wherein small streams falling from a considerable height, might be advantageously employed; certainly not meaning or expecting that every or any house in Front or Water Street should be so occupied: I give it merely in illustration of the purposes to which the principle can be applied. No body, I presume, will deny that a small stream falling from a great height (that is with a great head) may far exceed in power a much larger stream that is shallow. Supposing the water could be, as it can be, conveyed from Schuylkill by steam engines, so as to supply a great number of small manufacturies conveniently situated with power enough to drive a few spindles or a loom or two, would not the erection of such engines ultimately pay a good rent to the proprietors, and greatly benefit small manufacturies, and the public of course? T. C.

MR. DUCKET'S PLOUGH. (PLATE.)

IN England, where agriculture is certainly better understood than in any other country in Europe; the land yields on the average of the Kingdom, 24 bushels of wheat per statute acre. This is managed by keeping it in heart either by

1st. Manure; every farmer in England making his dung and compost heap the first object of his attention.

2dly. By rotation of crops; in such a way that two grain crops never succeed each other; but are separated by a grass crop, or

else (not a fallow, but) a fallow crop: and high manuring for a potatoe crop precedes wheat.

3dly. By fallow-crops; fallows for the destruction of weeds being nearly given up all over the kingdom. A fallow crop, is one that will admit, and will require the ground in the intervals to be kept constantly free from weeds by hand hoeing, or hand weeding, like potatoes.

4thly. By making the grass land subservient to the arable. That is, so proportioning the meadow and the arable, that, the cattle fed on the former will supply dung enough to manure about one fourth of the whole farm every year.

But where, notwithstanding every precaution in collecting dung, and forming compost heaps, manure is scarce; as it always will be where the farm has too large a proportion of arable land, and the farm is understocked with sheep and cattle; then recourse is had to ploughing-in a green crop. This practice I have seen pursued now and then with much pleasure in Pennsylvania, where buckwheat is the crop usually ploughed down when just coming into flower. In England, the common plant used for this purpose is the tare or vetch vicia, sativa, aulgaris. But the common plough, either of England or this country, is inadequate to the performance of this very useful part of farming, with neatness and effect. I therefore present my readers with a plate of Mr. Ducket's skim-coultered plough, which gained the premium given by the Duke of Bedford, as well as the gold medal of the Board of Agriculture. It is taken from the 43d vol. of the Annals of Agriculture, for the year 1805. The editor of that work observes very justly that, "To think of attempting to plough-in any green crop by way of manure, or a long stubble, or the plentiful fragments left of a crop of tares, or weeds, or long dung, (with the common plough) is an idle expectation: no other plough will effect it. But this instrument executes the work in perfection. The skim is applicable to any plough." T. C.

POLITICAL ECONOMY.

MR. EDITOR,

THE controversy about manufactures and commerce being rivals, seems to me very ridiculous. Every nation that has any claim to civilization must exercise agriculture, manufacturing and commerce: in proportion as the labour and capital of a nation are duly divided into these grand branches of human occupation, will the country be independent, the citizens happy, and serviceable to each other.

Except air, every thing necessary to the support of human existence, whether in the savage or civilized state, must be procured by labour: it is true a drink of water is come at with less trouble than a tumbler of wine; but still it requires exertions to get it. And pumps, wells, and aquaducts, are as important to society, as ships, clerks, and desks.

Without going into this controversy, which borders so closely on absurdity, let us temperately examine a few calculations that may throw some light on the subject of manufactures. Though Philadelphia, in many circumstances, does not resemble the cities of Europe, it will form a tolerable rule for the United States, it will therefore answer to exemplify, and to simplify the calculations. The population may be taken at 100,000, it is not much over or under this estimate, nor will an error here effect the general result.

1st. In a population of 100,000, it is probable there are 2,000 young boys and girls, not at school or engaged in any business; but from prejudice, pride, and other causes, many of their parents would not send them to work; let the number be reduced to 1000, and experience gives reason to suppose, they could at manufactures gain on an average $1 25 a week.

2d. There are also a number of young women who sew, bind hats, shoes, work for taylors, &c. but whose time, from want of employment, is not more than half occupied, and in consequence experience considerable distress; their number may be estimated at 500, and from the wages they now receive experience a loss, from this want of employment, of at least $1 50 a week.

3d. There is also a large body of labourers whose occupation is suspended three months in the year, their number is at least 400: the class exceeds this; but as they get occasional employ, those who are absolutely idle are estimated at 400, whose wages would be $5 a week.

4th. There is a number of elderly persons, whose strength is too much decayed for the toil of labourers or hired servants, and occupations where manufactories do NOT exist; who could be useful where they do; including both sexes, their number may be taken at 400, and wages estimated at $3 50 a week.

5th. Beside the preceding account of entirely lost time, there is a considerable portion of many families that would be employed in branches of manufactures that admit of being given out; such as tambouring, sewing up stockings, &c. &c. and supposing only one family in twenty took an interest in this, it would give 1000, whose industry would certainly produce $1 a week.

Now, without taking into account what would be gained by the capitalists who carried on the business—the merchants who sold the raw material and bought the manufactured goods—the increased demand for the produce of agriculture—the spring given to already existing trades—and the general effect on the country by such a creation of wealth, and keeping the circulation of money in the country; let us form an estimate of one year's gain of this 100,000 people, who are but a small proportion of the eight million now belonging to the United States.

First class, 1000 boys and girls at $1 25 a week would in the year produce	$ 65,000
2d Class, 500 young women, $1 50	39,000
3d Class, 500 labourers *out of* employ three months in the year, $5 a week	32,500
4th Class, 400 elderly persons, &c. $3 50	72,800
5th Class, 1000 families, at $1	52,000
	$ 261,300

To carry on this business, not less than seven or eight hundred thousand dollars would be required for the manufacturing capital; independent of the mercantile capital, direct and indirectly connected with it. J. R.

I am much obliged to my respectable friend and correspondent for this short but practical paper: it will come home to the understandings and feelings of many readers who, like himself, would regard my lucubrations and Dr. Bollman's, as useless and absurd. However, each of us in our way: we shall each of us do good to such of our readers, as may perchance be excited to *think* on these subjects. I would just observe, that although agriculture, manufactures, and commerce, are all necessary to a

civilized country, desirous of remaining civilized, yet it may prove a question neither useless or absurd to sit down and occasionally count the cost.

It has been proposed to raise silk worms, and manufacture indigo in England: and that nation was ready to go to war about Falkland's Island, and Nootka Sound, and Oczakoff: would the raising of mulberry trees and silk worms aid the agriculture, or the produce of indigo, keep the manufacture, or the commercial wars about these distant places, assist the commerce of that country? Is it a question of no importance, whether we shall protect a trade that brings us in a hundred thousand dollars, by a naval force that costs us half a million? Is it ridiculous to consider whether we shall support a manufacturing or commercial speculation, which would of itself be forever a losing concern to those embarked in it, if the rest of the nation were not taxed to afford them profit? May we not without much *waste* of time, expend an hour or two, in considering the relative value to the community, of capitals embarked in argriculture, manufactures and commerce respectively? I have readers of both opinions.

T. C.

NOTICES.

M. Berzelius is announced as having analyzed azot into 45 hydrogen, and 55 oxygen. We must wait for the details of the experiment, before we can give full credit to this important result.

I cannot insert Mr. Graafs communication in this number for want of room: nor Mr. Latrobe's, or Mr. J. Cutbushs's (which I much wished to include in the present number) for want of engravings for their figures; which I have now in train to be cut in wood. I want to add my own remarks to each of these papers. My trials met with the same result as Mr. Cutbushs'. They shall be inserted in the next Emporium.

Mr. J. Conrad is about publishing Davy's Chemical Elements of Agriculture: and Mr. Dobson goes on with Bancroft on permanent colours. I have perused both works; and they are well worth recommending to those who are interested in the pursuits they relate to. I rejoice to hear also of a new edition of Dr. Barton's Botany.

Mr. J. Cutbush has published the *Artists Manual*, 2 vols. 8vo. closely printed: (Johnson and Warner, and Fisher, South Fourth street.) This work contains the substance of Aikin's Chemical Dictionary, the Domestic Encyclopedia, and some similar publications. I do not know any book that includes so much scientific knowledge bearing upon manufactures, in the same compass, or at so small a price. I regard it as a compilation, made with judgment, and great industry, and a valuable addition to the useful literature of the country

I have not room in this number for an account of the loom that weaves by water power, or steam, invented, as I am informed by Mr. Siddal, at the calico printing works, about half a dozen miles on the New York road from Philadelphia. I shall gladly say more on this very important improvement. I have examined it with great satisfaction.

NEW DISCOVERY.

Thursday Evening, January 20, 1814.

Iode or Violaceous Gas. The Royal Society met after the holidays, when a paper from Sir H. Davy was read, describing a new and important discovery. About two years ago, a Parisian manufacturer of salt-petre, using all kinds of sea weed as a substitute for Barilla, discovered that his vessels were excessively corroded by a particular substance of a beautiful violet colour; he communicated the fact to some Paris chemists, but no particular notice was taken of it until Sir H. Davy went to Paris.

This new substance is easily procured by pouring sulphuric acid on the residuum of sea weed after the carbonat of soda has been extracted. It appears that all the vegetable products of the sea shore, yield it when thus treated. By pouring the acid on the residuary ashes of the sea weed, this new and most beautiful violet coloured gas is obtained.

The French propose calling it *iode* gas (from the Greek word *ion*, violet) but Sir H. D. prefers the term *violaceous* gas, as most suitable to English phraseology; its combination with hydrogene he agrees may be called *hydro-iodic gas*, &c. Its properties are equally important to the scientific chemist and manufacturer as a dye and pigment. It is the heaviest known gas; 100 cubic inches weighing 95-5. grains—it is easily disengaged at the temperature of 156; at a low one, it condenses into fine violet coloured chrystals; it is rapidly absorbed by the metals, uniting with iron, mercury, tin, lead, and zinc, and changing them into salts of the most beautiful tints of yellow, orange and brown. It has many analogies with oxygen, the alkalies, and chlorine or oxy-muriatic acid. Like the alkalies it has great affinity to oxygen, from which it can be expelled by heat; it experiences no change by the action of the voltaic pile, yet rapidly combines with phosphorus, hydrogen, and all the muriats; it is a non-conductor, is very slightly combustible, yet it is a supporter of combustion. It is so easily united with all the common metals, and converts them into such fine pigments, that before as many months elapse in this country, after its discovery, as years have done in Paris, it will be prepared by all our colour manufacturers, and used by our cabinet makers, wood stainers, and dyers. The existence of this substance tends to support an opinion of Sir H. D. that acids and alkalies do not depend on any peculiar acidifying principle, but on certain modifications of matter. All the iodats of iron zinc, are soluble in ether and spirits of wine, and many of them in water.

Alexander & Phillips, Printers, Carlisle.